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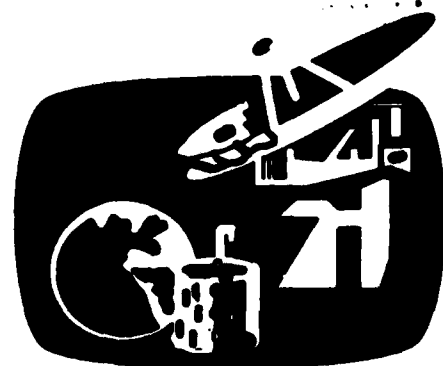
Protocol Interoperability Between DDN and ISO Protocols

(ASQBG-C-89-021)

August 1988

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115 O'Keefe Building
Georgia Institute of Technology
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PROTOCOL INTEROPERABILITY
BETWEEN DDN AND ISO PROTOCOLS

-- A Study and Specification Report --

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1. INTRODUCTION

This chapter gives a brief summary on the background of data communication protocols in the Defense Data Network (DDN) environment and the International Organization for Standardization (ISO) community. It also describes the motivations which stimulated this study task. The objectives of the study task and the structure of the report are also described in this chapter.

1.1 BACKGROUND

In December of 1978, the internetwork protocol suite, The Internet Protocol (IP) and the Transmission Control Protocol (TCP), was recognized and adopted by the Department of Defense (DoD). Since then, it has been well developed in Defense Data Network (DDN) environment and many other academic data networks. The protocol set is well recognized by DDN community as it satisfactorily meets the U.S. military requirements with respect to security, survivability, and reliability. It is also well recognized by the rest of the data communication community as it successfully provides network and transport services to end-users, and the vision of the original architects in the mid-70s is remarkably well-matched to today's data communication need.

On the other hand, the International Organization for Standardization (ISO), especially the Technical Committee 97 in ISO, along with some other standards organizations such as the International Telephone and Telegraph Consultative Committee (CCITT), have been developing high-quality standards for networking services, protocols, and interfaces for Open System Interconnection (OSI) in years. It is felt even more urgent in the past few years, with the rapid evolution of communication technologies and the system architectures, to the construction of distributed application environment with more advanced data communication standards, by a very large community of computer system builders. Some resulting standards have already been recognized as international standards. The ISO IS 8473 as a Network Layer protocol and ISO IS 8072/8073 as a Transport Layer protocol are two examples. In the United States, these protocols and some other layer's protocols have been adopted with minor modifications by the National Bureau of Standards (NBS) for some governmental organizations, and implemented by several vendors on a few systems. The ISO protocols are more favorable in the European countries, such as in the NATO member countries.

Under these circumstances, the critical problem of interoperability has arisen in interconnecting those independent DoD communities with other federal, intelligent, security, and commercial agencies in U.S., with other international organizations, and with the rest of NATO. This research is addressed to study the interoperability issues between the DDN protocols (TCP/IP) and the OSI protocols (TP-4).

1.2 MOTIVATIONS

In 1985, under the request by the DoD and NBS, the Committee on Computer-Computer Communication Protocol in the National Research Council did a transport protocol study of the DoD TCP/IP and the ISO Transport Protocol Class 4 (TP-4) [NRC 85]. The result shows that both protocols are functionally equivalent, both provide essentially similar services, and both are sufficiently equivalent in security-related properties. This study recommended with three alternative approaches for the DoD to solve the interoperability problem:

- 1) Immediately specify the TP-4 as a costandard -- for newly added systems to reduce the transition cost later.
- 2) Announce the intention to have TP-4 as a costandard -- to wait for the satisfactory demonstration of the protocol and implementation suitability; and to wait to use commercial products with low developing cost.
- 3) Continue to use the TCP, delay the adoption of the TP-4 -- to avoid faulty system behavior and unnecessary delay.

When more than one protocol is concerned in the data communication community, there must be the compatibility problem to be faced before and after the new protocol is adopted, until all the protocols are truly unified with unique standard protocol set. This is one of the reasons which stimulated this study.

Meanwhile, it is NATO's intention to introduce ISO protocols as far as possible in all NATO's new systems, some valuable research efforts were performed in the SHAPE Technical Center, as a joint effort with U.S. DoD, in the area of conversion between TCP and ISO transport protocols [GROEN 86]. The direct conversion method was studied as a method of achieving interoperability between the NATO and DDN data communications systems. However, the approach imposes quite a few restrictions on the transport service users to resolve the mismatches. So the second reason for this study is to find some alternative approaches to relax the restrictions on the transport service users.

Started in 1986, the Network Working Group in ARPANET proposed in RFC 1006 to implement ISO Transport Protocol Class 0 (TP-0) services on top of the TCP. The basic idea is that the TCP/IP protocols provide the error-free virtual circuit connections between transport service users so that only TP-0 of the ISO transport service is needed to interconnect DDN with the ISO protocol world. This approach could help the transition from the TCP/IP protocol suite to the ISO protocol suite. But there are some other issues which need to be further discussed. This is the third reason for the study task.

The pace of implementing ISO TP-4 is relatively slow, while the interests in TCP/IP increased dramatically recently. IBM and some research institutes in European countries jumped to TCP/IP in last six months. A study result released in December, 1987 shown that 56 percent of those surveyed are still willing to stay on TCP/IP with no plan to migrate to ISO. The implication of this survey means that it is going to be possible to have TCP/IP networks that have ISO protocols running simultaneously with TCP/IP protocols.

The ISO protocols have long been recognized as the trend of the protocol development. While the TCP/IP protocols have already occupied a large market, it will be inevitably required to have the well-developed protocol conversions between the DDN TCP/IP and the ISO TP. This is another reason that the protocol conversion could be quite important in the near future.

1.3 OBJECTIVES

This study is focused on the following problems:

- 1) The general issues involved in the protocol conversion;
- 2) The protocol conversion in the DDN to ISO environment;
- 3) More detailed understanding of both protocol suites;
- 4) Approaches to achieve the interoperability between TCP/IP and TP-4;
- 5) Proposal to the future studies in the area.

1.4 STRUCTURE OF REPORT

The report is divided into four major sections. Part I contains

discussions about the interoperable protocols environment in DDN in the future. Part II and III are devoted to the DDN and ISO protocol suites. Part IV is for the protocol conversion between the TCP/IP and the TP-4.

PART I. INTEROPERABLE PROTOCOLS IN DDN ENVIRONMENT

In this section, the major issues in the protocol conversion are presented. The protocol interoperability requirements in the DDN environment are discussed. The protocol conversion tasks are defined to meet the requirements.

2. MAJOR ISSUES IN THE PROTOCOL CONVERSION

During 1987 there was a lot of controversy in the development gatewaying strategies. Since it is inevitable to have heterogeneous networks coexisting in the data communication community, the protocol conversions will be a permanent fact of life. For example, today we are concerned about the gatewaying between DDN TCP/IP community and the ISO/OSI protocol communities in the same digital data communication world. Soon we will find ourselves concerned with the gatewaying between the global telephone network with integrated services (ISDN) and the global Wide Area Network with digital data communication (GWAN). Some experts are arguing that the ISO/OSI protocol architecture should be considered as a worldwide standard architecture toward which all existing architectures should converge in the long term. Other experts argue that only an intermediate protocol for the protocol conversions in the near term should be considered.

The significance of the gateway design for protocol conversion is based on the principle that ALL the protocol layers above the gatewaying layer must be compatible. This rule should be strictly reserved in the gateway design. The gateways implemented at the network layer (DDN IP and ISO IP) are of limited general use in the long term. Some of the arguments indicate that gatewaying should occur at or above the transport layer. And some arguments also suggest that the best approach is to perform gatewaying exactly at the transport layer to minimize the gatewaying effort.

Gateways can be implemented at the transport protocol peer or at the transport service access point. When this approach is used, how should the end-to-end reliable service property at the transport layer be maintained? How should its significance be evaluated in the military environment where the survivability is critical important? When the service primitive is not provided by one of the converted protocols, should it become the restriction imposed on the service users? Should it be resolved by the protocol conversion mechanism in the gateway as much as possible? Should more intelligence in the conversion be

considered to handle the mismatches? Should direct packet-to-packet conversions be preferred for higher throughput with more restrictions on the user side? The last question is how the low throughput and performance should be improved for heavy duty gateways? These are questions which must be addressed in this research.

3. PROTOCOL INTEROPERABILITY REQUIREMENTS IN DDN

It is a well-recognized trend in the data communication protocol development to converge to the ISO standardized protocols. As suggested by the report from the transport protocol study group in the National Research Council, the DDN community should be ready to have the protocol convergence in certain future time period [NRC 85]. On the other hand, the delayed availability of the ISO TP-4 implementations is causing more user groups jumping over to the TCP/IP internetworking protocols. The effect of the current situation will definitely put more importance onto the protocol conversion task when the conversion is actually needed.

3.1 Interconnecting DDN and ISO Networks

This is the basic problem of interconnection between two network systems, such as the TCP/IP-based DDN in the U.S. and the ISO based network in the rest of NATO. Figure 3.1 shows this internetworking scenario. Only one set of protocol suite is implemented in each network in this case. The gateway is required to interconnect the two networks.

This kind of interoperability is always required before any protocol transition or convergence plan is made.

3.2 Interconnecting TCP and ISO Users in the Same Network

This is the problem that both the TCP/IP and the ISO protocols coexist in the same network as costandards. The network here could be a set of interconnected subnetworks. Two protocol suites can coexist in any subnetworks. The users using different protocol suites are communicated through the intermediate gateways, as shown in Figure 3.2. The DDN Internet is an example of the case.

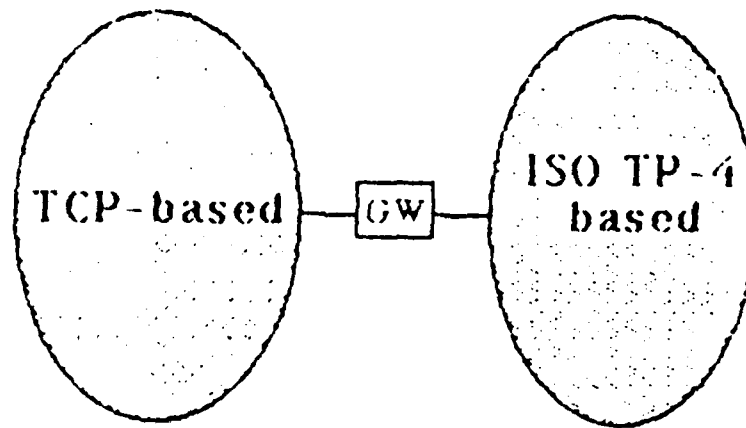


Figure 3.1 Interconnecting the TCP-based Network with the ISO-based Network

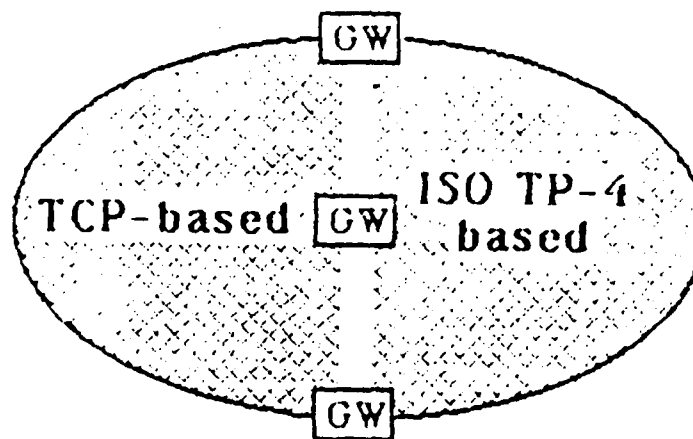


Figure 3.2 Interconnecting TCP/ISO Users In the Same Network

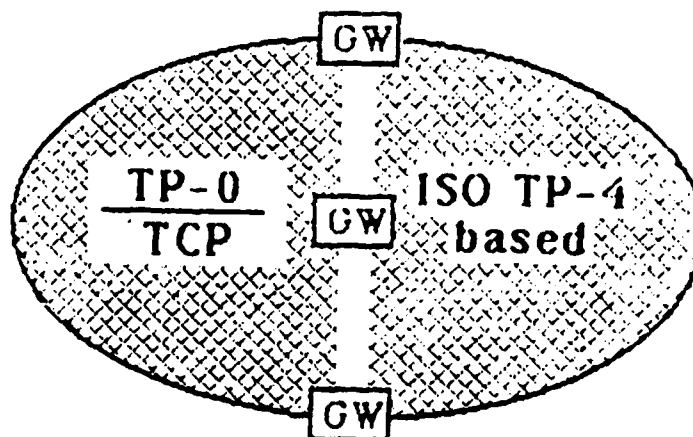


Figure 3.3 Interconnecting TP-0/TCP users with the Rest

3.3 Interconnecting TP-0 Users with the Rest

This is the case where ISO TP-0 services are implemented on some nodes above the TCP/IP protocols, as proposed in [ROSE 87]. As higher level services and protocols above the transport layer are usually implemented as user-callable utilities on the host computers, it is desirable to offer them directly in the DDN Internet now without disrupting existing facilities. This will permit DDN users to develop expertise with ISO applications while there is still a lot of work being done to get good implementations of ISO transport/network layers. It will also permit more graceful convergence and transition strategy from TCP/IP networks to the ISO-based networks in the medium and long term. The interconnection model is shown in Figure 3.3. This migration strategy is based on the notion of gatewaying between the TCP/IP and ISO protocol suites at the transport layer.

4. PROTOCOL CONVERSION TASKS

The problem of protocol conversion will be discussed from three aspects: general gateway functions, gateway functions required in the DDN environment, and gateway functions attended in this study task.

4.1 GENERAL GATEWAY FUNCTIONS

Internet gateways, regardless of their application environment, must perform a variety of functions in order to make data communications between different networks compatible [MART 87b]. The functions of generalized internet gateways are discussed here:

1. Medium Transformation - A gateway must translate messages between different transmission media, such as LAN RF broadband or baseband digital signals, and the serial 1822 or X.25 interfaces of the DDN packet switching nodes. Signaling schemes to each network must be present in the gateway.
2. Media Access Translation - The media access schemes on the LAN side of the gateway must be present in the gateway. Media access schemes on LANs, such as CSMA/CD or token passing 802.4, must be present in the gateway. Access schemes to the DDN must also be present.
3. Address Translation - Network addressing schemes are

different on each network, so that the gateway must perform address translation. For example, the IEEE 802.3 LAN uses a 48 bit flat addressing scheme and the DDN uses a 32 bit two-level addressing scheme. The gateway must recognize internet addressing schemes when interconnecting multiple networks.

4. Protocol Transformation - The network protocols of each network must be transformed through decapsulation and encapsulation steps in L part of the gateway. For the DDN, the Internet Protocol (IP) and the Transmission Control Protocol (TCP) must encapsulate to a LAN message. The LAN protocol headers must be stripped before hand-off to the TCP/IP protocols. In the case of internet environment, a gateway-to-gateway protocol must be implemented.
5. Message Buffering and Flow Control - The gateway must be able to buffer messages from each network and flow control the network interfaces when the buffers are full. The flow control mechanisms buffer sizes are critical to the performance of the gateway.
6. Reliable Connection Management - The gateway must provide an error free link between two end-users on the networks by adhering to the error control and re-transmission mechanisms in the network protocols. The status of the connection must be made available to the user when error conditions arise.
7. Fault Detection and Reporting - The gateway must be able to detect connection status when establishing and maintaining a connection between two end-users. The gateway then reports to the users the condition of the links, gateways, and networks in the connection path, if a problem should occur.
8. Performance Monitoring and Statistics - The gateway must be able to monitor its performance relative to packet throughput and network routing statistics. These parameters can be read locally or remotely from the gateway and used for internet management.
9. Security Control Mechanisms - The gateway must adhere to internet security control and management procedures. This might include generation and routing of encryption keys and cryptographic algorithms.
10. Real-Time Response - The gateways must process packet traffic from the networks in real-time so that user response times are not compromised. The gateway must accommodate the differences in network response times. Real-time response is also important during interactive user sessions. The gateway must sustain the communication rates of each network.
11. Parallel Processing Architecture - The gateway must contain parallel processing architecture to sustain the network transmission speeds. Dedicated protocols and communication modules must exist to achieve the performance throughput

required by connection to multiple networks.

12. ISDN Interfaces - Gateways must eventually interface to integrated services digital networks (ISDNs) for data, voice, and video communications. The gateway must interconnect to ISDNs and their predecessors.
13. Multiple Network Interconnection - Gateways in distributed C3 systems must have the interfaces and link parts to access multiple communications systems and networks.
14. Multi-Level Security and Key Distribution - Communications between end-users in the distributed C3 system will require multi-level security for sensitive information and the gateway must preserve the data security characteristics of several networks.
15. Dynamic Network Topology Reconfiguration - Since the gateways are interconnected to multiple networks it is feasible to use the gateway to keep network status and give this information to the network management function for reconfiguration when nodes and networks fail or are destroyed.
16. Network Reachability - The gateway must determine the reachability and availability of neighboring networks. Network status must be exchanged between gateways so that alternate network hops be taken when a path is down.
17. Internet Management and Control - The gateway interacts with an Internet Management and Control Center to assist in the daily operation and reliability of the networks. The gateway performance monitoring function collect performance data and presents it to the Control Center.

4.2 GATEWAY FUNCTIONS BETWEEN DDN AND ISO/OSI

4.2.1 Differences between Network and Transport Layer Gateways

Figure 4.1 and 4.2 show the major difference between the network layer gateways (IP gateway) developed in the previous research work and the transport/network layer gateways in the current researches [MART 87a]. In the IP gateway case, it is concentrated on the connectability up to the network layer. The medium transformation, the media access translation, and the subnetwork protocol translation are performed in the IP gateway, while the same Internet Protocol and the same upper layer protocols are used. Gateways at the Network Layer are called

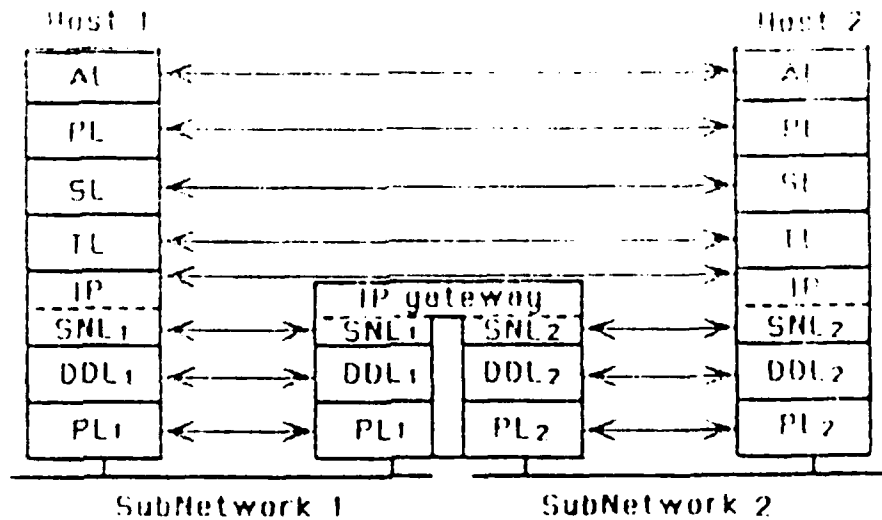


Figure 4.1 The IP Gateway Model

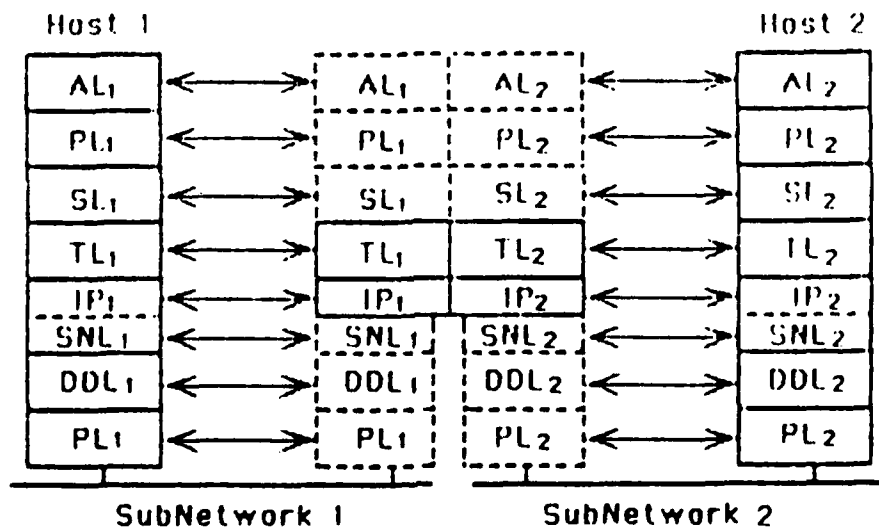


Figure 4.2 The Model of Transport/Above Gateway in Concern

Routers [MART 87b].

In the second case, more complicated functions are performed in gateway than those in the router case. As a result, it increases the complexity of the gateway design. While the gatewaying at the higher layers (Session, Presentation, and Application layers) are optional, depending on the case concerned. These situation will be described in the following sections.

4.2.2 Three Cases of Transport Layer Gateways in DDN

The cases discussed in following section can be applied to both situations explained in Section 3.1 and 3.2: interconnecting DDN and the ISO based networks, and interconnecting TCP/IP users and ISO protocol users within the same network. This is based on the fact that the differences at the lower layers up to the network layer are not important issues here.

Case one implements not only the Transport/Network layers, but also other upper layers, as shown in Figure 4.3. The gateway itself actually becomes a node in both networks, performing store-and-forward functions between application layer protocols. This kind of gateway will be able to connect the TCP/IP based DDN world with the ISO protocol based networks without changing anything in the DDN.

The advantages of this approach are:

- 1) the least effort is needed by the user nodes in the DDN side;
- 2) the gateway implementation could be simple using a host computer to be connected to both networks, running both sets of protocol separately in multi-tasking environment, performing message translation at the user level; or performing the application protocol conversion at the application layer [MART 87a,b].

The disadvantages of this approach are:

- 1) lower throughput in the gateway,
- 2) longer node delays,
- 3) low performance when used for the interactive message transferring,
- 4) that the gateway becomes the single point of failure in the

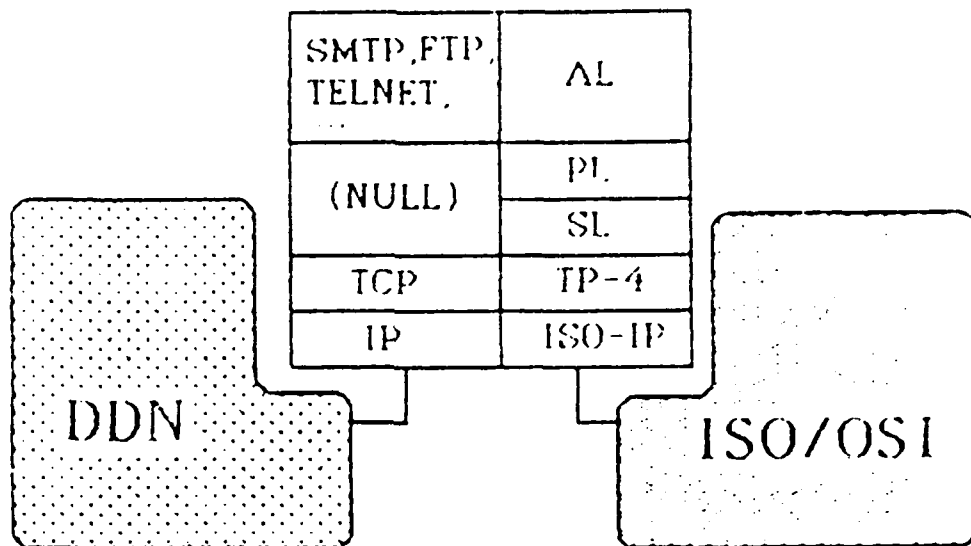


Figure 4.3 Gateway with Upper Layer Protocols Implemented
(Case One)

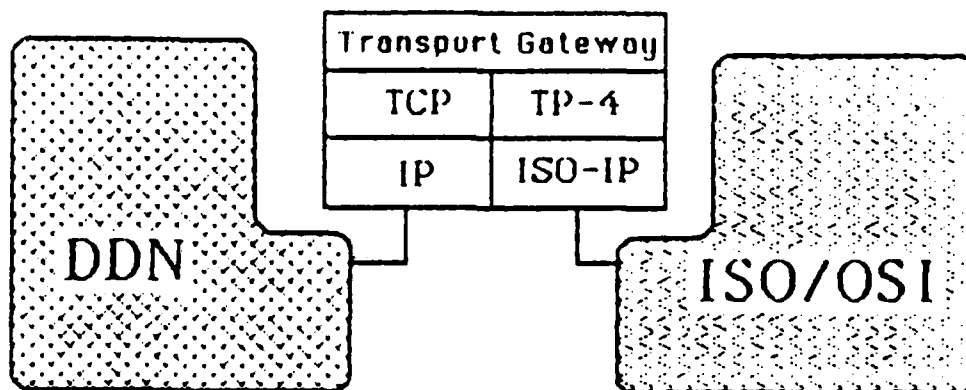


Figure 4.4 Transport Layer Gateway without Upper Layers
(Case Two)

DDN environment where the survivability is critical.

Case two implements the protocol conversion at the network and the transport layers, as shown in Figure 4.4. This approach requires the ISO upper layer protocols being implemented on those DDN nodes whose users want to communicate with the users in the ISO based networks.

The advantages of the approach are:

- 1) If the protocol conversion is implemented at the protocol peer entity at the transport layer, the end-to-end property of the connection between the end users can be sustained. This is very important in the DDN environment for survivability;
- 2) This is more reasonable approach for protocol convergence in the future.

The disadvantages of this approach are:

- 1) The implementation of the gateway is more complicated due to the complexity of the protocol at the transport layer;
 - 2) Only those users with ISO upper layer protocols implemented in the node can communicate with other nodes.
- Figure 4.5 shows the model of Case Three. The TP-0 protocol at the top of the TCP is considered in this approach, but it is not necessary the only choice. Actually, it is considered as a general study. The different classes of ISO Transport services are not compatible by the nature. Gatewaying is needed to get the users with different classes of transport services communicated and could be quite easily extended to the actual situation in real need. One example could be the connections to long haul networks implementing LAN protocols. As discussed in some papers, this approach is considered to reduce the overhead of overly complicated protocols.

4.2.3 Proposed Transport Gateway with Multiple Functions

Putting the three models from previous discussion together, a multiple-function gateway is discussed in this section. The multiple function transport gateway structure is shown in Figure 4.6.

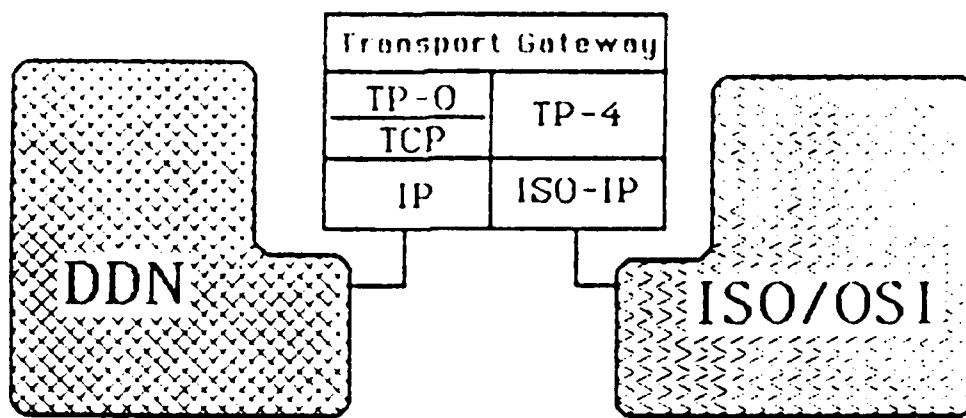


Figure 4.5 Transport Layer Gateway with TP-0 on Top of TCP
(Case Three)

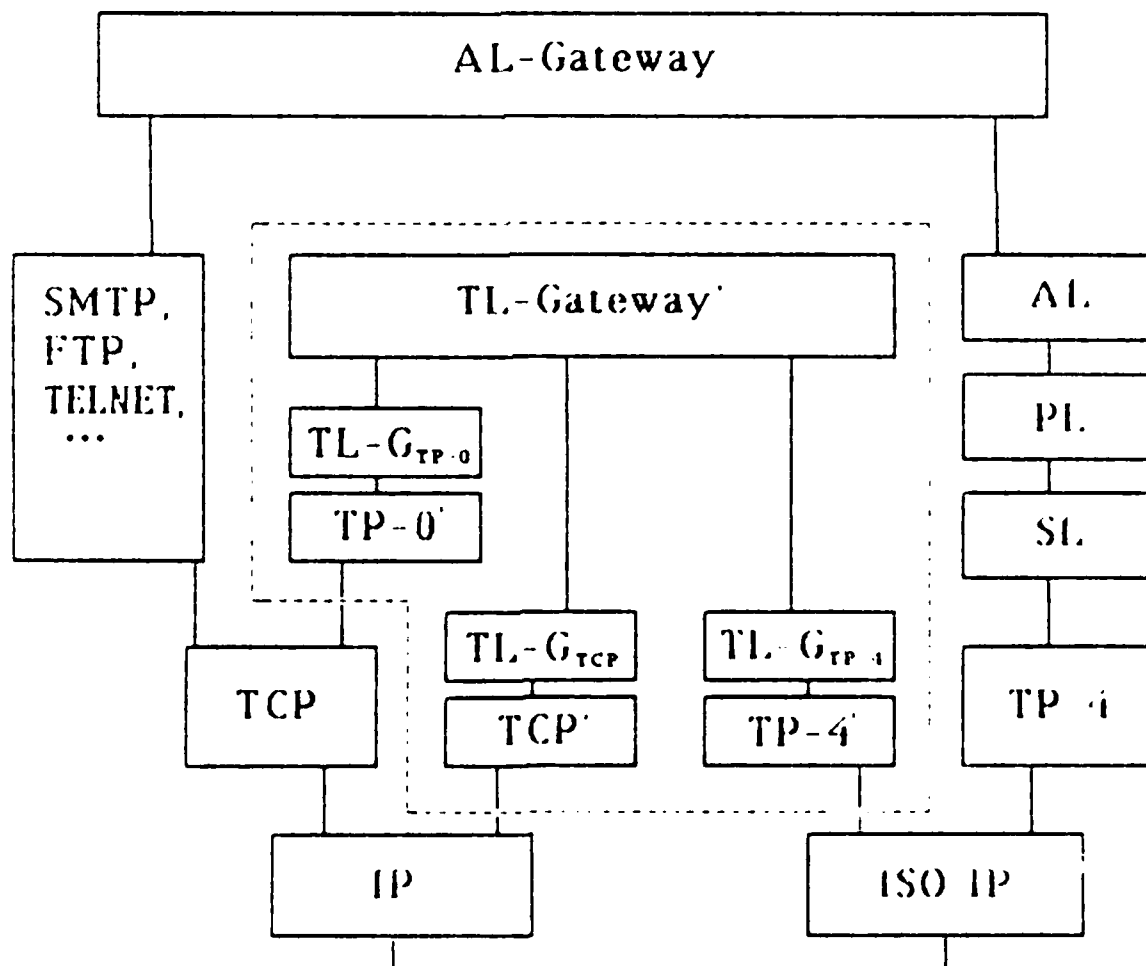


Figure 4.6 Multiple-function Transport Gateway

Following notations are used in the Figure 4.6:

IP: DDN Internet Protocol
TCP: DDN Transmission Control Protocol
SMP,FTP,TELNET: DDN Application Layer Protocol

ISO IP: Equivalent Internet Protocol in ISO (CLNS, 8473)
TP-4: ISO Transport Layer Protocol, Service Class 4
SL: ISO Session Layer Protocols
PL: ISO Presentation Layer Protocols
AL: ISO Application Layer Protocols

AL-Gateway: DDN-ISO Gateway at/above Application Layer

TL-Gateway': Transport Gateway, link submodule
TL-G TCP : Transport Gateway, interface submodule to TCP
TCP': Transport Gateway, TCP submodule
TL-G TP-4 : Transport Gateway, interface submodule to TP-4
TP-4': Transport Gateway, TP-4 submodule
TL-G TP-0 : Transport Gateway, interface submodule to TP-0
TP-0': Transport Gateway, TP-0 submodule

The AL-Gateway module in the figure performs the gatewaying at/above the application layer, in order to interconnect the upper layer protocols between DDN and ISO world. The protocol conversion in this model is discussed as Case Three in the previous section.

The Transport gateway module is made of several submodules. To interconnect different transport layer protocols, a general link submodule is used to perform gatewaying tasks independent of particular transport protocols. The protocol-dependent tasks, such as checksum production, reproduction, and error detection, are performed in the protocol-specific submodules. The gaps between the protocol-specific submodules and the general link submodule is matched up by the interfacing submodules. The mismatches between the interconnected protocols will be notified to both sides. Some of the conflicts are handled in each interfacing submodules, and some others are handled in the general link submodule. Some decision-makings are required in the link submodule. Another phase of research determined the functions which are candidates for protocol negotiation in the gateways.

4.3 GATEWAYING CONCERNED IN THIS STUDY

This study examines the issues and design approaches related to transport layer gateways. The gateway functions are performed by

the TL-G submodules in Figure 4.6 (surrounded by the dash lines). The protocol conversion tasks and the conversion algorithms will be specified in the last part of the report.

5. FUNCTIONAL ELEMENTS CONCERNED IN THE TRANSPORT GATEWAYS

This chapter presents some explanations and definitions to those terminologies related to the functional elements in transport and network layers, based on the OSI model. Special issues are also discussed for those functional elements which requires special processing in the transport gateways.

5.1 CONNECTION MANAGEMENT

Connection at N-layer is an association established between the N-layer peer entities to be used by the users above the N-layer. The peer entities in the connection are identified by their addresses, or service access points. Usually, the N-layer protocol user initiates the N-layer connection establishment. The complexity of the connection establishment operation at different layers is dependent on the specific layer. The connection establishment at the N layer requires that the (N-1) layer connection is available and both N-layer peer entities are in the state in which they can execute the connection establishment protocol exchange. Otherwise, some manipulation should take place to handle the exception. There are different options in the connection establishment. In some protocols, three-way handshaking are used. Some protocols allow data transferring by the connection establishment protocol exchange.

The release of the N-connection is normally initiated by one of user above the N-layer. It may also be initiated by one of the peer entities at the N-layer as a result of an exception occurred at the N-layer or the layer below. The user data may be lost upon this condition. The orderly release of the N connection requires protocol exchanges between the N-layer peer entities. One example is the common reference to time in the connection release.

The connection establishment at the transport layer is more complicated functional element, and quite versatile between different transport protocols. Special cares are required in the transport gateways. For example, when the connection establishment is initiated by the TCP user through the gateway to the TP-4 user at the other side, the transport gateway needs to act as the TCP peer entity and the TCP user in order to get the

connection established and to get complete information from the initiating TCP peer entity. It also needs to act as the TP-4 user and TP-4 peer entity in order to establish the connection to the destination TP-4 user. Since the transparency should be available during the operation, more intelligence is required in the transport gateway. Another example is to resolve the difference in the addressing. The solution to this problem can be very complicated, depending on the addressing schemes involved.

5.2 DATA TRANSFER

User data and control information are transferred between peer entities using protocol-data-units (PDUs). Several functions are required in the gateway for the operation.

An expedited PDU is a service PDU which is transferred and processed with higher priority over that of normal PDUs. It is used to transfer small amount of data infrequently, such as for signaling and interrupt purposes. An expedited PDU is transferred independently from flow control over the normal data, and is guaranteed to be delivered before any subsequent normal PDU or expedited PDU can be sent on the connection.

- Special care is needed in the gateway design for the data transfers. For example, TP-4 allows to piggybacking user data on a connection establishment, while TCP does not support this option. TP-4 supports the expedited data transfers, while TCP supports the PUSH option in the normal data transfers.

5.3 FLOW CONTROL

Flow control is the function which controls the amount of data flowing within a layer or between adjacent layers. The flow control which regulates the data rate between peer entities at the same layer is called peer flow control. The flow control which regulates the data rate between N-entity and (N-1) entity is called layer interface flow control. There exist several flow control mechanisms, and the "sliding window" is one such technique.

5.4 SEQUENCING

Sequencing is the function which preserves the order of PDUs

being transferred between peer entities. It is required when the received data may not be guaranteed to be in the same order as they are delivered. Sequencing usually requires additional protocol control information.

5.5 MULTIPLEXING AND DEMULTIPLEXING

Multiplexing at the N-layer is the function by which more than one N-connections are supported by a single (N-1) connection. As protocol data are multiplexed by the sender, demultiplexing should be performed by the receiver to get the protocol data recovered for different connections.

5.6 SPLITTING AND RECOMBINING

Contrary to the multiplexing, splitting at the N-layer is the function that one N-connection is supported by more than one (N-1) connections. As protocol data are splitted at the sender, recombining should be performed at the receiver to recover the protocol data.

5.7 SEGMENTING, BLOCKING, AND CONCATENATION

Segmenting is the function at the sender which maps one data unit into multiple data units, or packets. Reassembling is the reverse function of segmenting on the receiver side. Blocking is a function which maps multiple data units into one data unit at the same layer. Deblocking is performed at the other side as the reverse function. Concatenation is a function which maps multiple N data units into one N-1 data unit. Separation is required at the other side as the reverse function.

5.8 ROUTING

Routing is the function which enables communication to be relayed by a chain of entities. The routed communication may be transparent to both higher and lower protocol layers. Most of routing function is performed at the network layer. The routing function is a special important issue in the network layer gateway design for internetworking environments. Routing algorithms must account for differences in internet addresses.

5.9 ERROR HANDLING

Error handling function may be performed in several ways in the OSI layers. An acknowledgment mechanism may be used to obtain a higher probability of detecting data unit loss. The data-unit is made uniquely identifiable, so that the receiver can inform the receipt or nonreceipt of the data unit. The sender may take remedial action accordingly. Usually, the acknowledgment mechanism may require additional protocol control information. Other error detection and notification functions can also be used for the similar purpose, such as "checksum" and "frame check sequence" operations to detect the errors in the received data-units.

5.10 RESET

Reset is a function which sets the corresponding peer entities to a predefined state after some uncorrectable error conditions occur, such as the loss of synchronization. It may cause a possible loss or duplication of data, however, all protocol states are eventually reset.

5.11 MANAGEMENT

There exist three aspects of management in the OSI model. The Application-management, in the application layer, is related to the management of OSI application processes. The system-management relates to the management of OSI resources and their status across all layers of the OSI architecture. The layer-management relates to the management of specific layers, partly performed in the layer such as activation and error control and partly performed as a subset of system-management.

The following sections describes related protocols in the DDN environment and ISO/OSI architecture, based on the definitions described in this chapter.

PART II. THE DDN PROTOCOL SUITE

This and the following chapters explain the DDN internetwork protocol suite in detail, with the emphasis on the TCP and IP protocols. Readers who are knowledgeable in the DoD protocol suite can skip the sections on the internal protocol mechanisms. For readers, not versed in this area, the following sections offer a background required to understand the DDN and ISO protocols.

6. DDN INTERNET ARCHITECTURE

Besides the common requirements for data communication networks, the DoD has its own special requirements for the DDN internet architecture:

- 1) The security concern with data security and communication security;
- 2) The survivability concern with minimization of critical control nodes;
- 3) The reliability concern with adaptive, robust data distribution.

Accordingly, the DoD adopted the internetworking policy to implement the Transmission Control Protocol (TCP) on each host in the internet for the end-to-end reliable transport protocol. The Internet Protocol (IP), the Gateway to Gateway Protocol (GGP), and the Exterior Gateway Protocol (EGP) were defined for the intra- and inter-network communication protocols. The DDN Internet architecture and its protocol suite are shown in Figure 6.1. Following sections describes the IP and TCP protocols in detail. The GGP and EGP will not be discussed in the case that they are not closely related to this conversion task.

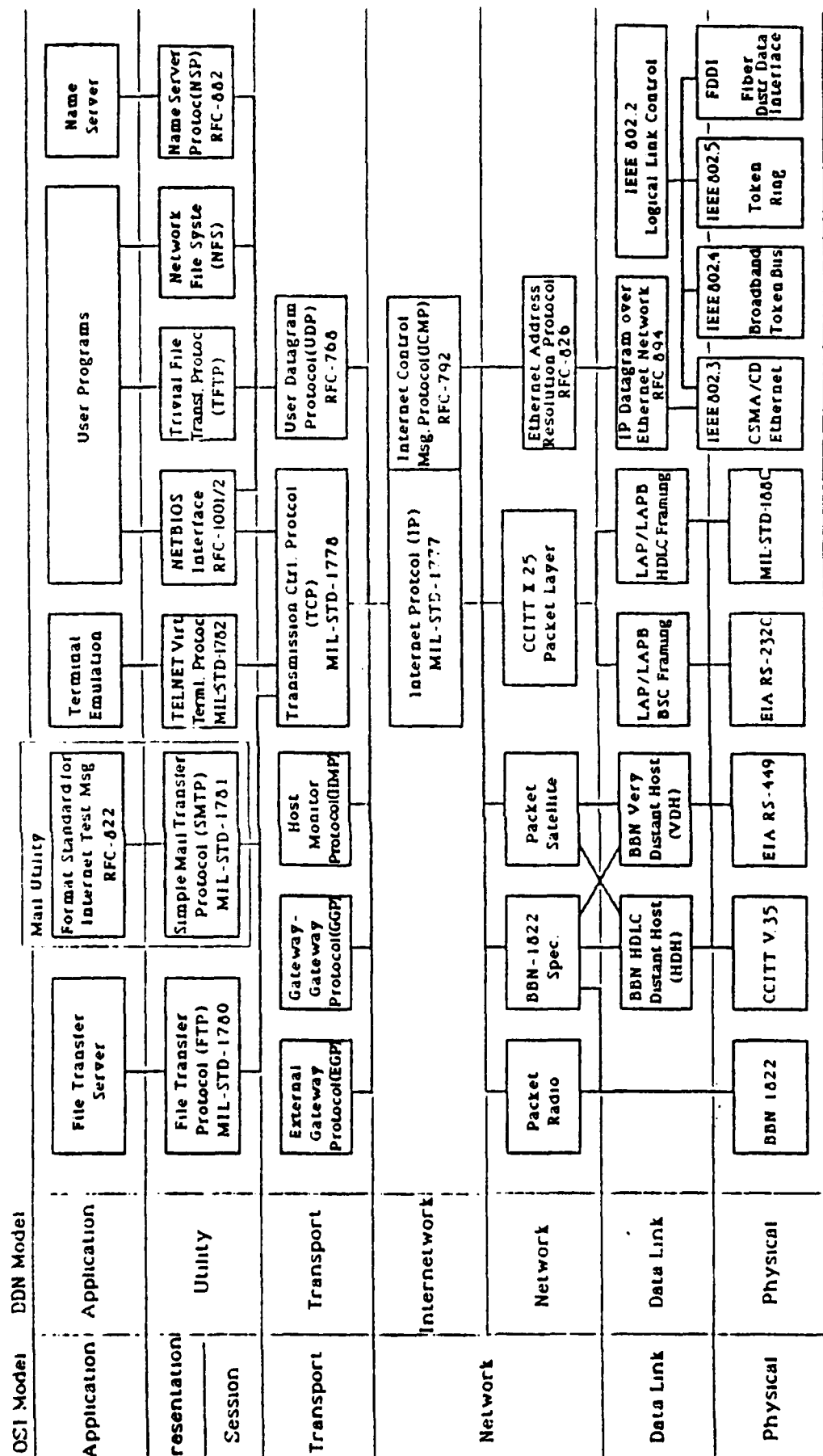


Figure 6.1 DDN Internetwork Architecture

Figure 6.1 DDN Internetwork Architecture

7. INTERNET PROTOCOL (IP)

The Internet Protocol (IP) provides the basic service for transmitting datagrams between source and destination hosts. It was located at the "Gateway" level in original DDN Internet architecture, and now it is located in the "Internetwork" sublayer as shown in Figure 6.1. The IP service is provided based on the various local network services underneath in the "Network" sublayer.

- 1) **Datagram Transfers.** The datagrams are blocks of data, or protocol data units (PDUs) in OSI Reference Model. In the DoD internetwork environment, a datagram is an independent data entity unrelated to each other. There are no connections or virtual circuits established. The PDUs are sent to the lower layers and no indication is received of their reaching the destination. The services for reliability in the data transmission are provided by higher layer protocol (e.g., TCP) above the Internet Protocol.
- 2) **Addressing.** The IP module resides in each network host and each gateway interconnecting networks. The source and destination addresses of the hosts are identified by a fixed length address field in the header of datagram (32 bits). The IP modules along the path transmit the datagrams from the source host through the intermediate hosts and gateways to the destination while making routing decisions to select the transmission path.
- 3) **Fragmentation and reassembly.** The IP module modifies the size of the datagrams by breaking the datagrams to small lengths and putting them back together later at the destination. IP does this when it is necessary to transmit long datagrams through "smaller packet" networks.
- 4) **Types and qualities of service.** It is a generalized set of parameters characterizing different service choices, to be used by gateways to select the actual transmission parameters for a particular network.

7.1 OPERATIONAL MODEL DESCRIPTIONS

The IP provides datagram service to upper layer protocols such as

TCP. It calls for services from Network layer and lower layers, depending on the networks connected. Detected errors at the IP layer are reported via the Internet Control Message Protocol (ICMP) which is required to be implemented with IP.

The data from the upper layer protocol module is passed to the local IP module with the destination address and other parameters as the arguments. The IP module prepares a datagram header with those arguments and attaches the data to it. It also determines, according to the destination address, the local network address for the immediate receiver (network node or gateway). The datagram is passed to the local network interface module. The local network interface module, in turn, creates its own packet, attaches the datagram to it, and sends it over to next immediate receiver. As the packet is received, the local network packet header will be stripped off, the datagram will be handed over to the IP module. That IP module will determine whether the datagram reaches the destination node. If not, it will decide how the datagram is to be forwarded to next receiver by the destination address. The operations will be repeated until the datagram reaches its destination. If the datagram reaches its destination, the IP header will be stripped off, and the data will be passed over to the upper layer protocol module.

The upper layer protocols may use logical names to indicate the destination host address. And mapping are performed as:

| Protocol level | Mapping task |
|----------------|---------------------------------------|
| Upper levels | logical name -- Internet address |
| IP level | Internet address -- local net address |
| Lower level | local net address -- routes |

It should be noticed that one host can have several physical interfaces (multi-homing) to local network, or a single physical host can use several distinct internet addresses, acting as if it were several distinct hosts.

The fragmentation takes place more than once along the path as necessary. When it happens, the data of the long datagram is divided into portions on a eight-byte boundary, and the datagram header will be duplicated for each new, shorter datagram. The total length field in the headers is adjusted to current actual length. The more-fragment flag of all but last datagram is set to one, and is copied from long datagram over to the last shorter datagram; the fragment offset field of all shorter datagrams is set to the sum of the original value of long datagram and the offset value among shorter datagrams, to ensure the correctness for multiple fragmentation. To assemble the fragments correctly, the data from datagrams with same identification, source and destination addresses, and protocol field values will

be arranged and combined according to the fragment offset field of each datagram.

7.2 PROTOCOL SPECIFICATION

The datagram header format of the IP is described in Figure 7.1.

Version (4 bits): The IP version is 4.

Internet Header Length (IHL, 4 bits): The length of datagram header in 4-byte words. The minimum IHL is 5 without any options. The maximal internet header is 60 bytes.

Type of Service (8 bits): These are parameters for the service choice, to specify the treatment of the datagram during its transmission through the system, as explained in Figure 7.2. It is actually a three way tradeoff between low-delay, high-reliability, and high-throughput. A 3-bit precedence field is included.

Total Length (16 bits): The length of the datagram in bytes. All hosts must be prepared to accept datagrams of up to 576 bytes.

Identification (16 bits): The identifying value assigned by the sender to help in assembling the fragments of a datagram.

Flags (3 bits): The control flag for fragmentation, as described in Figure 7.3.

Fragment Offset (13 bits): The offset location of this fragment in the assembled datagram, indicated in 8-byte words. The fragment offset for the first fragment is zero.

Time to Live (8 bits): The maximum time limit in seconds the datagram is allowed to remain in the internet system. It is set up by the sender, decreased by every IP module along the path, and the datagram is self-destructed when it becomes zero.

Protocol (8 bits): This field indicates the next level protocol used in the data portion of the internet datagram.

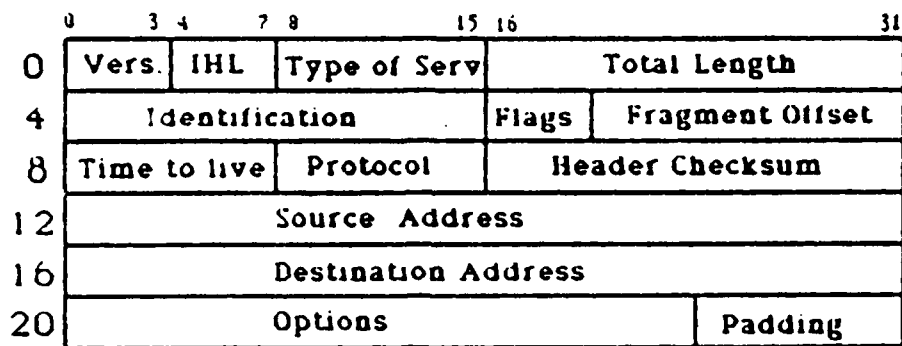


Figure 7.1 IP Header Format

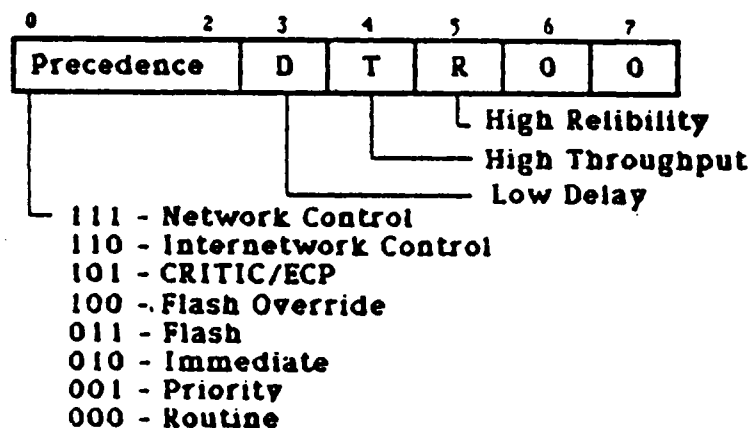


Figure 7.2 Type of Service in IP

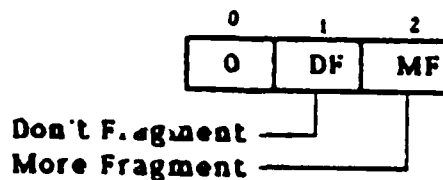


Figure 7.3 Flags in IP

Some of the examples are listed in Table 7.1.

Header Checksum (16 bits): It is one verification of correctness in the transmission. The checksum is on the header only, calculated as the 16-bit one's complement of the one's complement sum of all 16-bit words in the header. The value for this field is zero for the calculation. It is recalculated and verified at each point that the internet header is processed.

Source Address (32 bits)

Destination Address (32 bits)

There are three classes of internet addresses, as illustrated in Figure 7.4. These classes handle the different cases underlying subnetwork types.

Options (in variable length): It is another field that the IP users can use to specify the special treatment for the datagram, useful in some special situations, including timestamps, security, and special routing. Some examples are displayed in Figure 7.5.

7.3 INTERFACE DESCRIPTION

IP provides two kinds of service calls for upper layer protocols. But the actual implementation is more or less system dependent.

SEND (src, dst, prot, TOS, TTL, BufPtr, len, id, DF, opt) ==> result

Upon unsuccessful service calls, such as bad arguments, unaccepted datagram by local network, a reasonable report must be returned, such as the cause of the failure, to the IP user. The details of the report are up to the implementation.

RECV (BufPtr, prot) ==> (result, src, dst, TOS, len, opt)

When the IP module receives an incoming datagram from local network module, it will pass the information to the user, if the addressed user had a pending RECV call, by a pseudo interrupt or similar mechanism; or it will notify the addressed user. If the user does not exist, an ICMP error message will be returned to the sender, and the datagram is discarded.

Table 7.1 Examples of Upper Layer Protocols Using IP

| Decimal | Keyword | Protocol |
|---------|-----------|--------------------------------|
| 1 | ICMP | Internet Control Message |
| 2 | IGMP | Internet Group Management |
| 3 | GGP | Gateway-to-Gateway |
| 6 | TCP | Transmission Control |
| 8 | EGP | Exterior Gateway Protocol |
| 9 | IGP | private interior gateway |
| 11 | NVP-II | Network Voice Protocol |
| 17 | UDP | User Datagram |
| 18 | MUX | Multiplexing |
| 20 | HMP | Host Monitoring |
| 21 | PRM | Packet Radio Measurement |
| 27 | RDP | Reliable Data Protocol |
| 28 | IRTP | Internet Reliable Transaction |
| 29 | ISO-TP4 | ISO Transport Protocol Class 4 |
| 30 | NETBLT | Bulk Data Transfer Protocol |
| 31 | MFE-NSP | MFE Network Services Protocol |
| 32 | MERIT-INP | MERIT Internodal Protocol |
| 33 | SEP | Sequential Exchange Protocol |
| 63 | | any local network |

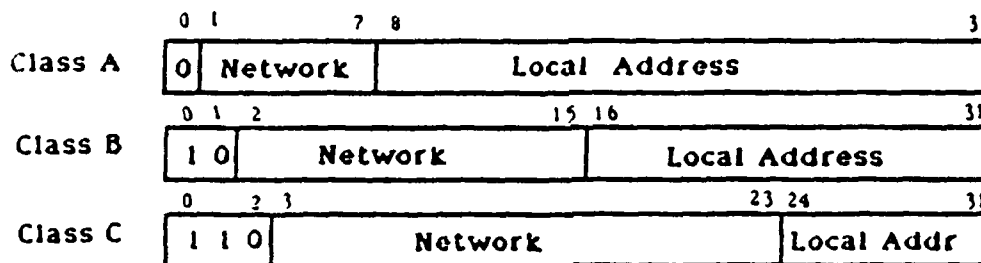


Figure 7.4 The Classes of Internet Addresses

| Copied | Class | Number | Length | Description |
|--------|-------|--------|--------|-------------------------|
| 0 | --- | --- | --- | Control |
| 0 | 0 | 0 | -- | End of option list |
| 0 | 1 | 1 | -- | No operation |
| 0 | 2 | 2 | 11 | Security |
| 0 | 3 | 3 | var | Loose source routing |
| 0 | 7 | 7 | var | Record route |
| 0 | 8 | 8 | 4 | Stream ID |
| 0 | 9 | 9 | var | Strick source routing |
| 2 | --- | --- | --- | Debugging & measurement |

Figure 7.5 Options of the IP

8. INTERNET CONTROL MESSAGE PROTOCOL (ICMP)

The Internet Control Message Protocol (ICMP) is actually realized in many implementations as an integral part of the IP module. ICMP provides the destination hosts or gateways with the error reporting facilities about problems in communication environment. The ICMP messages are treated by the IP module as the data portion of the datagram, when the "protocol" field of the IP header equals "1". The format for most ICMP messages are described in Figure 8.1. And the types of the ICMP messages with different code are listed in Table 8.1.

9. USER DATAGRAM PROTOCOL (UDP)

The User Datagram Protocol (UDP) provides a transaction oriented procedure for application programs to send messages with minimum protocol overhead. It assumes the IP as underlying protocol, when protocol field value equals 17. In UDP, delivery and duplicate protection are not guaranteed. It is quite similar to the ISO TP-0 which assumes that the underlying Network Layer can provide reliable datagram services. It is more suitable to applications which requires the least protocol overhead, and it is not so critical to lose a small part of the data. The UDP header format is shown in Figure 9.1. The major uses of UDP is the Internet Name Server, and the Trivial File Transfer.

10. TRANSMISSION CONTROL PROTOCOL (TCP)

The Transmission Control Protocol (TCP) is a connection-oriented, highly reliable end-to-end protocol between hosts in the interconnected packet-switching computer networks. By connection-oriented, it means that the TCP establishes, and maintains the virtual circuit, or connection, between two communicating processes on the source and destination hosts. It is assumed that only unreliable datagram services are provided as the underlying Network Layer protocol, and the TCP must recover from data segments that are damaged, lost, duplicated, or delivered out of order. The TCP is located at the Host Level in the DDN internetworking architecture as described in Figure 6.2, and at the Transport and part of Session Layers in the ISO - OSI reference model. Following functions are provided by the TCP.

| Type | Code | Checksum |
|---|------|----------|
| Unused | | |
| Internet Header + 64 bits of original datag | | |

Figure 8.1 ICMP Message Format

Table 8.1 Some Examples of ICMP Message Type

| Type | Code | Description |
|------|------|--|
| 0 | 0 | Echo Reply |
| 3 | 0 | Destination Unreachable |
| 3 | 0 | net unreachable |
| 3 | 1 | host unreachable |
| 3 | 2 | protocol unreachable |
| 3 | 3 | port unreachable |
| 3 | 4 | fragmentation needed and DF set |
| 3 | 5 | source route failed |
| 4 | | Source Quench |
| 5 | | Redirect |
| 5 | 0 | redirect for network |
| 5 | 1 | redirect for host |
| 5 | 2 | redirect for type of service & network |
| 5 | 3 | redirect for type of service & host |
| 8 | 0 | Echo |
| 11 | | Time Exceeded |
| 11 | 0 | time to live exceeded in transit |
| 11 | 1 | fragment reassembly time exceeded |
| 12 | 0 | Parameter Problem |
| 13 | 0 | Timestamp |
| 14 | 0 | Timestamp Reply |
| 15 | 0 | Information Request |
| 16 | 0 | Information Reply |

| | | | |
|-------------|----|-------------|----|
| 0 | 15 | 16 | 31 |
| Source-Port | | Destin-Port | |
| Length | | Checksum | |
| Data ... | | | |

Figure 9.1 User Datagram Protocol Header Format

- a. **Basic Data Transfer.** The TCP module accepts user data as a continuous stream of bytes, packages them appropriately into data segments with the TCP header, and calls the lower Network Layer module (e.g. the IP) to transfer the data. The user can also "push" the TCP module to deliver the accumulated data to the receiver immediately.
- b. **Reliability.** Each byte in the data stream conceptually has a sequence number. The sequence number of the first byte in the data segment is indicated in the TCP header. If the sender does not receive positive acknowledgment in a certain timeout period from the receiver, the data segment is assumed damaged or lost, and retransmitted. A checksum is also added to each data segment for receiver to detect and discard the damaged data. The sequence number is also useful for receiver to detect and discard the duplicated data, and to relocate the data segments which are delivered out of order.
- c. **Flow control.** The TCP provides the receiver with the "window" facility to indicate the allowed number of bytes that the sender may transmit before receiving further permission. Flow control operations proceed from this field.
- d. **Multiplexing.** Different applications on hosts are assigned with different "port" addresses, so that many processes in a single host can use the same TCP communication facilities simultaneously. The internet and the port addresses make a socket which uniquely identifies one side of a connection.
- e. **Connection.** The TCP initializes and maintains certain status information for each data stream for reliable data communications. It is called a connection, including sockets, sequence numbers, and window sizes.
- f. **precedence and security.** The TCP makes use of the "type of service" field and the security option for the service.

10.1 OPERATIONAL MODEL DESCRIPTIONS

The TCP module is usually implemented as a device in the file system of an operating system. After establishing a connection (similar to OPEN device), the application processes in computer hosts transmit data by calling on the TCP module through device driver and passing buffers of data as arguments. The TCP packages the data from these buffers into segments with the control

information to ensure the reliable transmission, and and calls on the IP module to transmit each segments to the destination TCP. The IP module will route the datagrams through local networks and intermediate gateways, fragment and reassemble them if necessary, as described in previous sections. The receiving TCP module will place the data from a segment into receiving user's buffer and notifies the user. The state transition of a connection in TCP over which data are transferred can be described by a finite state machine, as shown in Figure 10.1.

The **CLOSED** state represents no connection. If the local TCP receives a passive **OPEN** call from TCP user, it will create a transmission control block (TCB), fill the TCB with control parameters from the **OPEN** call, and change its state to **LISTEN** to incoming **OPEN** calls. On an active **OPEN** call, the TCB will be created, and the TCP will start the procedure to establish the connection at once.

TCP uses three-way handshake for the connection establishment. It is necessary because the initial sequence numbers are selected using local clock in a 4.55 hour period, not a global clock. The **LISTEN** TCP has no way of knowing whether it is an old delayed **OPEN** or not, and it must ask **OPEN** initiator to verify it.

The data transfer proceeds in the **ESTAB** state.

When the local TCP receives a **CLOSE** call from user, it will send a **FIN** packet to remote TCP, and change to **FIN WAIT-1** state. The remote TCP will send back an **ACK**, notify its user through the return parameters of any user call, and stay in **CLOSE WAIT**. Data transfer can still be performed at this moment. When the remote TCP receives a **CLOSE** from its user, it will send a **FIN** packet, wait for acknowledgment, and change to **CLOSED** state. The local TCP will send an **ACK** packet to remote TCP, wait for 2 MSec **TIME-WAIT**, and change to **CLOSED** state.

The state of the connection, along with other control parameters, are stored in the transmission control block (TCB). Those parameters include send sequence variables (initial send sequence number, segment sequence number for last window update and send window, send unacknowledged, next send sequence number, etc.); receive sequence variables (similar to send sequence variables); and current segment variables (segment sequence number, acknowledgment number, length, window, urgent pointer, and precedence value). TCP module maintains the connection status upon incoming user calls or incoming packets.



10.2 PROTOCOL SPECIFICATIONS

The TCP header, described in Figure 10.2, is sent along with user data as the data portion of the internet datagram, immediately following the IP header.

Source Port (16 bits)

Destination Port (16 bits)

Ports are used in the TCP to name the ends of connections for the communication. For the purpose of providing services to unknown callers, some service contact ports, also called "well-known ports", are pre-defined, and some examples are listed below in Table 10.1.

Sequence Number (32 bits): The sequence number of the first byte in the data segment. If the packet is SYN for OPEN request, this field contains the Initial Sequence Number (ISN).

Acknowledgment Number (32 bits): The sequence number of the data byte the receiver is expecting to receive, when the ACK control bit is set.

Data Offset (4 bits): The length of the TCP header in 32 bits word.

Control Bits (6 bits): The Bit pattern is shown in Figure 10.3, and the meaning is explained below:

- URG: Urgent Pointer field significant
- ACK: Acknowledgment field significant
- PSH: Push function
- RST: Reset the connection
- SYN: Synchronize sequence numbers
- FIN: Finish, no more data from sender

Window (16 bits): The number of bytes the receiver is will to accept. It is started from the byte indicated in the acknowledgment field.

Checksum (16 bits): The checksum for all 16-bit words in the header text, and a 96-bit pseudo header. It is calculated as the one's complement of the one's complement

sum of all 16-bit words.

Urgent Pointer (16 bits): The offset of the end of urgent data from the sequence number, when the URG control bit is set.

Options (variable length): TCP module must implement all options.

| Kind | Length | Meaning |
|------|--------|---|
| ---- | ----- | ----- |
| 0 | - | end of option list |
| 1 | - | no-op |
| 2 | 4 | maximum segment size, indicated in 16-bit field |

10.3 THE INTERFACE DESCRIPTIONS

There exist two kinds of interfaces: the User/TCP interface, and the TCP/IP interface. The upper protocol layers use the user/TCP interface to communicate with TCP.

10.3.1 The User/TCP Interface

The User/TCP interface is realized by the calls by the TCP users to the TCP module.

OPEN (local_port, foreign_socket, active/passive, [,timeout]
[,precedence] [,security/compartment] [,options])
==> local_conn_name

This call is used by TCP user to establish a connection with the destination host with the address indicated by the foreign_socket.

If the active/passive flag is set to passive, it is a call to LISTEN for incoming connection, for any call if the foreign_socket is unspecified, or for a particular call if the foreign_socket is fully specified.

The timeout gives a time limit on delivering the user data. If the user data is not successfully delivered within the time limit, the connection is aborted. The default value for timeout is 5 minutes.

The TCP module accept incoming requests only if the

security/compartment information is exactly the same, and the precedence is equal or higher than that in the OPEN call.

SEND (local_conn_name, buf_addr, bytes, PUSH, URGENT, [,timeout])

This call is used by the TCP user to send data over the TCP connection.

In handling the data transfer, the TCP module will send the data in the buffer immediately to the receiver if the PUSH flag is set; otherwise, the data may be combined with data from subsequent SENDs for the efficiency.

When the URGENT flag and the urgent pointer is set, the receiving TCP will signal the TCP user if the data preceding the urgent pointer has not been consumed yet. It is used to stimulate the receiver to process the urgent data.

RECEIVE (local_conn_name, buffer, bytes) ==> bytes, URGENT, PUSH

This call is used by the TCP user to allocate a receiving buffer associated with the connection. The buffer will be filled with as much incoming data as it can hold if there is no PUSH flag set in incoming packet. Otherwise, the buffer will be returned with partially filled data.

CLOSE (local_conn_name)

This call is used to close the specified connection, after gracefully transmitting outstanding SENDs. In this case, the CLOSE from TCP user means only "no more data to SEND", but not means "no data will be received".

ABORT (local_conn_name)

This call is used to cause all pending SENDs and RECEIVES to be aborted, the TCB to be removed, and special RESET message to be sent to the TCP module on the other side.

STATUS (local_conn_name) ==> status data

The status data returned includes: local and foreign sockets, local connection name, receive and send window, connection state, number of buffers awaiting acknowledgment and pending receipt, urgent state, precedence, security/compartment, and transmission timeout.

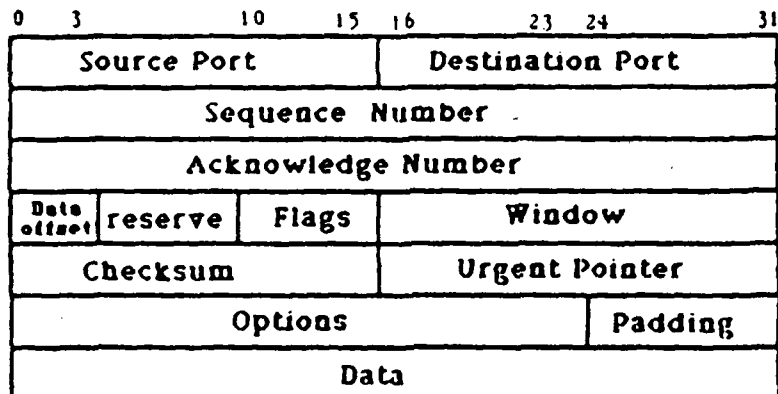


Figure 10.2 The TCP Header Format

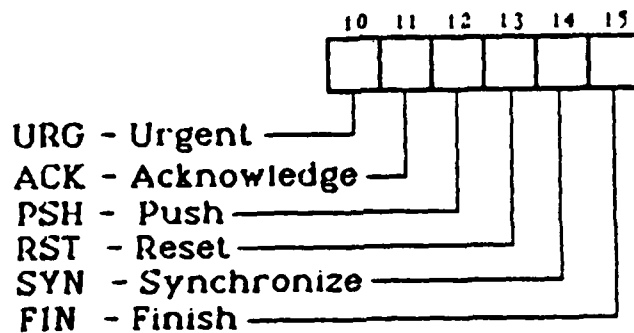


Figure 10.3 The Bit Pattern of Control Bits

Table 10.1 Examples of TCP Ports

| Decimal | Keyword | Description |
|---------|-------------|------------------------------------|
| 5 | RJE | Remote Job Entry |
| 7 | ECHO | Echo |
| 9 | DISCARD | Discard |
| 11 | USERS | Active Users |
| 13 | DAYTIME | Daytime |
| 19 | CHARGEN | Character Generator |
| 20 | FTP-DATA | File Transfer [Data] |
| 21 | FTP | File Transfer [Control] |
| 23 | TELNET | Telnet |
| 25 | SMTP | Simple Mail Transfer |
| 37 | TIME | Time |
| 39 | RLP | Resource Location Protocol |
| 41 | GRAPHICS | Graphics |
| 42 | NAMESERVER | Host Name Server |
| 43 | NICNAME | Who Is |
| 49 | LOGIN | Login Host Protocol |
| 51 | LA-MAINT | IMP Logical Address Maintenance |
| 53 | DOMAIN | Domain Name Server |
| 63 | VIA-FTP | VIA Systems - FTP |
| 65 | TACACS-DS | TACACS-Database Service |
| 67 | BOOTPS | Bootstrap Protocol Server |
| 68 | BOOTPC | Bootstrap Protocol Client |
| 69 | TFTP | Trivial File Transfer |
| 71 | NETRJS-1 | Remote Job Service |
| 72 | NETRJS-2 | Remote Job Service |
| 73 | NETRJS-3 | Remote Job Service |
| 74 | NETRJS-4 | Remote Job Service |
| 93 | DCP | Device Control Protocol |
| 95 | SUPDUP | SUPDUP |
| 97 | SWIFT-RVF | Swift Remote Vitural File Protocol |
| 101 | HOSTNAME | NIC Host Name Server |
| 102 | ISO-TSAP | ISO-TSAP |
| 103 | X400 | X400 |
| 104 | X400-SND | X400-SND |
| 105 | CSNET-NS | Mailbox Name Nameserver |
| 107 | RTELNET | Remote Telnet Service |
| 109 | POP-2 | Post Office Protocol |
| 113 | AUTH | Authentication Service |
| 115 | SFTP | Simple File Transfer Protocol |
| 117 | UUCP-PATH | UUCP Path Service |
| 119 | NNTP | Network News Transfer Protocol |
| 123 | NTP | Network Time Protocol |
| 125 | LOCUS-MAP | Locus PC-Interface Net Map Server |
| 127 | LOCUS-CON | Locus PC-Interface Conn Server |
| 129 | PWDGEN | Password Generator Protocol |
| 133 | STATSRV | Statistics Service |
| 136 | PROFILE | PROFILE Naming System |
| 137 | NETBIOS-NS | NETBIOS Name Service |
| 138 | NETBIOS-DGM | NETBIOS Datagram Service |
| 139 | NETBIOS-SSN | NETBIOS Session Service |
| 243 | SUR-MEAS | Survey Measurement |

10.3.2 The TCP/IP interface

The TCP module calls IP module to Send and Receive data over networks. The interface to IP is described in Section 7.3. The default values for the type of service in IP are listed below:

| | |
|---------------|----------|
| Precedence: | routine |
| Delay: | normal |
| Throughput: | normal |
| reliability: | normal |
| Time to Live: | 1 minute |

PART III. THE ISO/OSI PROTOCOL ARCHITECTURE

In this and following chapters, the OSI basic reference model and the ISO Session, Transport, and Network Layer protocols are reviewed. This section of ISO protocol studies and previous section of TCP/IP protocol studies should prepare the reader for the transport layer gateway discussion in the next section.

11. THE ISO AND THE OSI REFERENCE MODEL

To avoid the confusion with the ISO standard's documentation, the ISO organization and the standards documentation procedures are explained in this chapter. It also describes the OSI basic reference model, and gives the global view of the ISO protocols.

11.1 THE ISO AND THE ISO STANDARDS DOCUMENTING

The International Standards Organization, or ISO, is a world-wide organization for producing the international standards in all areas. It is divided into Technical Committees (TC), SubCommittees (SC), and Working Groups (WG) to deal with problems in specific branches of different areas. The technical committee 97 (TC97) is specialized in the information processing systems. There are three subcommittees in TC97 related to the Open System Interconnection (OSI), as described in Figure 11.1. Other working groups not in the figure include Computer Graphics, Conceptual Schema, Database Languages, Data Descriptive File, and Text and Office Systems.

All international standards are processed through the ISO in a similar way. Each working group works on the Working Drafts for the required standards, labeled as

ISO/TC#/SC#/ [WG#/] N#

After step-by-step approval, it becomes Draft Proposals (DP), Draft International Standards (DIS). After the approval on a DIS ballot, the DIS becomes an international standard (IS). DP, DIS, and IS are labeled by

ISO DP #, or
ISO DIS #, or
IS #

Technical Committee 97 - Information Processing Systems

TC97/SC6

Telecommunications and
Information Exchange
Between Systems

WG1 - Data Link Layer

WG2 - Network Layer

WG3 - Physical Layer

WG4 - Transport Layer

WG5 - Architecture of Layer 1-4

TC97/SC13

Interconnection of
Equipment

WG1 - Process Interfaces

WG2 - Interface Standards Administration

WG3 - Lower-Level Interfaces

TC97/SC21

Information Retrieval, Transfer,
and Management for Open
Systems Interconnection

WG1 - OSI Architecture

WG4 - OSI Management

WG5 - Application/Presentation Layers

WG6 - Session Layer

Figure 11.1 ISO Organization Chart

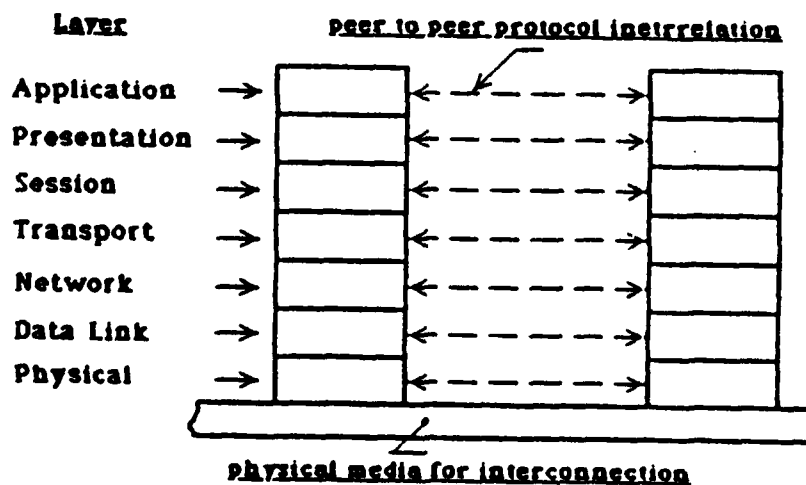


Figure 11.2 OSI Basic Reference Model

where the number # is kept the same. The amendment to the international standards is produced in the same way, except labeled as Working Draft, Draft Proposed Addendum (DPAD #), Draft Addendum (DAD #), and Addendum (AD#). The ISO standards are reviewed periodically, usually on a five-year cycle.

11.2 THE OSI BASIC REFERENCE MODEL

The Open System Interconnection (OSI) basic reference model was developed to provide a common basis for the coordination of standards development while allowing existing standards to be placed into perspective within the model. The model provides a conceptual and functional framework for the definition of services and protocols within the boundaries. It includes sufficient flexibility to accommodate advances in technology and expansion in user demands, so as to allow teams to work productively and independently in standards development. It is intended to ease the tasks to identify areas for developing or improving standards, and to provide a common reference for maintaining consistency of all related standards.

In ISO standard 7498 [ISO 7498], the definitions and environment of Open system Interconnection, and the modeling of the OSI environment is introduced. It describes the concept of a layered architecture as a basic structuring technique. Open systems in the OSI reference model are decomposed into seven layers, as shown in Figure 11.2. Similar functions in OSI are grouped into the same layer so as to localize changes, to minimize and standardize interfaces, and to facilitate creating sublayers for optional, specific functions. This standard also describes, by layers, the definition, the services provided to upper layer, and the functions within the layer for each of the seven layers in the OSI reference model. Table 11.1 summarizes the OSI layers and services.

11.3 ISO STANDARDS

The ISO standards documents currently available cover a large range of different areas, and many of them are still the draft proposals (DP). Table 11.2 contains a list of ISO documents related to the OSI.

Table 11.1 OSI Layers and Services

| Layer | Services |
|-----------------------------|---|
| 7 Application Layer | <ul style="list-style-type: none"> *provides end-users with comprehensive interface into all kinds of distributed information services (document distribution, electronic mail, distributed transaction processing) |
| 6 Presentation Layer | <ul style="list-style-type: none"> *identifies, negotiates communications transfer syntax *formats data (binary, ASCII, EBCDIC, graphics, numerics) *provides special transformation (compression, encryption) |
| 5 Session Layer | <ul style="list-style-type: none"> *provides session-connection establishment, and release *supports application process dialog *exchanges normal and expedited data |
| 4 Transport Layer | <ul style="list-style-type: none"> *provides for establishment, data transfer, and termination of logical connections between session entities *provides end-to-end information interchange and control *provides error detection and recovery |
| 3 Network Layer | <ul style="list-style-type: none"> *provides network routing and connection services *segments and blocks network messages *provides expedited data transfer *provides error detection, recovery, and notification |
| 2 Data Link Layer | <ul style="list-style-type: none"> *initializes and disconnect data link between adjacent nodes *transfers data over link *provides error detection and correction |
| 1 Physical Layer | <ul style="list-style-type: none"> *provides physical interface through electrical, mechanical, procedural, and functional means |

Table 11.2 ISO / OSI Documents

| ISO/OSI Doc | Description |
|-----------------------------------|--|
| <u>General:</u> | |
| IS 7498 | OSI Basic Reference Model |
| TR 8509 | Service Conventions |
| DP 8807 | LOTOS - Description of the Temporal Ordering Specification Language |
| DP 9074 | ESTELLE - A Formal Description Based on an Extended State Transition Model |
| <u>Application Layer:</u> | |
| DIS 8571 | File Transfer, Access and Management |
| DIS 8649 | Definition of Common Application Service Elements |
| DIS 8650 | Specification of Protocol for Common Application Service Elements |
| DIS 9040 | Basic Class Virtual Terminal Service |
| DIS 9041 | Basic Class Virtual Terminal Protocol |
| <u>Presentation Layer:</u> | |
| DIS 8822 | Connection Oriented Presentation Service Definition |
| DIS 8823 | Connection Oriented Presentation Protocol Definition |
| DIS 8824 | Specification of Abstract Syntax Notation One (ASN.1) |
| DIS 8825 | Basic Encoding Rules for Abstract Syntax Notation One (ASN.1) |
| <u>Session Layer:</u> | |
| DIS 8326 | Basic Connection-Oriented Session Service Definition |
| DIS 8327 | Basic Connection-Oriented Session protocol Specification |
| <u>Transport Layer:</u> | |
| IS 8072 | Transport Service Definition |
| IS 8073 | Transport Protocol Specification |
| DIS 8602 | Protocol for Providing the Connectionless-mode Transport Service |

Network Layer:

| | |
|----------|--|
| DIS 8208 | X.25 Packet Level Protocol for Data Terminal Equipment |
| DIS 8348 | Network Service Definition |
| IS 8473 | Protocol for Providing the Connectionless-mode Network Service |
| DIS 8648 | Internal Organization of the Network Layer |
| DIS 8878 | Use of X.25 to Provide the OSI Connection-mode Network Service |
| DIS 8881 | Use of the X.25 Packet Level Protocol in Local Area Networks |
| DIS 8882 | X.25--DTE Conformance Testing |

Data Link Layer:

| | |
|----------|---|
| IS 4335 | HDLC Procedures - Consolidation of Elements of Procedures |
| DIS 7478 | Multilink Procedures |
| IS 7776 | HDLC Procedures - X.25 LAPB-Compatible DTE Data Link Procedures |
| IS 7809 | HDLC Procedures - Consolidation of Classes of Procedures |
| IS 8471 | HDLC Balanced Classes of Procedures - Data Link Layer Address Resolution/Negotiation in Switched Environments |
| DIS 8802 | Local Area Networks |
| DIS 8885 | HDLC Procedures - General Purpose XID Frame Information Field Content and Format |
| DIS 8886 | Data Link Service Definition for OSI |

Physical Layer:

| | |
|-----------|---|
| SC6/N3631 | Physical Service Definition |
| DIS 2110 | 25-pin DTE/DCE Interface Connector and Pin Assignments |
| DIS 4902 | 37-pin DTE/DCE Interface Connector and Pin Assignments |
| DIS 4903 | 15-pin DTE/DCE Interface Connector and Pin Assignments |
| DIS 8480 | DTE/DCE Interface Back-up Control Operation Using the 25 Pin Connector |
| IS 8481 | DTE to DTE Physical Connection Using X.24 Interchange Circuits with DTE Provided Timing |
| DIS 8482 | Twisted Pair Multipoint Interconnections |
| DIS 8877 | Interface Connector and Contact Assignments for ISDN Basic Access Interface Located at Reference Points S and T |
| DIS 9067 | Automatic Fault Isolation Procedures Using Test Loops |

11.4 CONCEPTS OF CONNECTION- AND CONNECTIONLESS-MODE

Another important concept related to this protocol conversion task is the concepts of Connection-mode and Connectionless-mode transmission. In the ISO documents, these modes are called connection-oriented and connectionless services, respectively.

A connection, in the formal terminology of the OSI Reference Model, is an association between two or more peer-entities established for data transfer. In addition to three distinct phases of Connection Establishment, Data Transfer, and Connection Release operations, and distinguishable lifetime of those phases, it has following fundamental characteristics:

- 1) It involves establishing and maintaining of two or more party agreement concerning data transfer between the peer-entities and the layer providing the service;
- 2) It allows the negotiation among all the parties concerned of the parameters and options that will govern the data transfer;
- 3) It provides connection id in which the overhead associated with address resolution and transmission can be avoided during the data transfer phase;
- 4) It provides a context in which successive data units transferred between the peer-entities are logically related, and therefore with the preservation of sequence and provision of flow control.

These connection oriented characteristics are attractive in a wide range of applications which call for relatively long lived, stream-oriented interactions between entities in stable configurations.

In contrast, the connectionless-mode transmission, or so called "message-mode", "datagram", "transaction mode", and "connection free", has always played an important role. It is basically the transmission of a single data unit from a source service-access-point to one or more service-access-points without establishing a connection, by performing a single service access. It has following fundamental characteristics:

- 1) It requires only a pre-existing association between the peer-entities involved, without any peer-to-peer agreement in using the service;
- 2) All the information required to deliver a data unit

(addresses, quality of service, options, etc.), together with data transmitted, is presented to the layer providing the connectionless-mode service in any single service access. As a result, it may also be true that

- 3) Each data unit transmitted is entirely self-contained and can be routed independently;
- 4) Copies of a data unit may be transmitted to a number of destination addresses.

The characteristics of the connectionless-mode transmission are attractive in applications which involve short-term request/response interactions, exhibit a high level redundancy, must be flexibly reconfigurable, or derive no benefit from guaranteed in-sequence data delivery.

Protocols in some layers are described separately in the transmission modes. DIS 8473 defines the standard for providing connectionless-mode network service (CLNS), very similar to that of DDN Internet Protocol (IP). Both DDN TCP and ISO-TP feature connection-mode transport service. The next two sections describe the ISO Network and Transport layer services and protocols.

12. THE NETWORK LAYER

The Network Layer provides the means to establish, maintain and terminate network-connections, and the functional and procedural means to exchange network-service-data-units between transport-entities, with the independence from routing and relay considerations.

12.1 NETWORK SERVICE DEFINITION (DIS 8348)

This standard defines the Network Service in OSI Reference Model, and Network Service primitives, mainly for connection-mode type.

12.1.1 The Network Service

The Network Service provides for the transparent data transfer between its users.

1) End-to-end data transfer:

All routing and relaying functions are performed by the Network Service provider.

Independent of underlying transmission media. It relieves the users from all concerns regarding how data are transferred over various heterogeneous subnetworks.

Data transparency. Data transferred are not restricted for the content, format, coding, structure, or meaning.

2) User addressing. It utilizes a system of addressing (NSAP addressing) to allow users to refer unambiguously to one another.

3) Quality of Service Selection. It provides the users with a means to request and to agree the quality of service, such as

throughput;
transit delay;
transfer failure probability; and
residual error rate which is defined as

$$RER = \frac{N(\text{lost}) + N(\text{error}) - N(\text{extra})}{N(\text{total})}$$

where N is the number of packets.

More services are included in the connection-mode network service:

1) Network-connection establishment and release;

2) Reset to predefined state;

3) Flow control;

4) Expedited data transfer;

5) More quality of service selection:

Network-connection establishment delay;
Network-connection establishment failure probability;
Network-connection resilience;
Network-connection release delay;
Network-connection release failure probability;
Network-connection protection;
Network-connection priority;
Maximum acceptable cost.

12.1.2 Network Service Primitives

Table 12.1 gives a summary of connection-mode Network Service primitives.

12.2 NETWORK PROTOCOL SPECIFICATION (IS 8473: CONNECTIONLESS-MODE)

The protocol specified in this standard provides the connectionless-mode Network Service, very similar to the internetwork datagram service provided in the DDN Internet Protocol (IP).

12.2.1 Underlying Service and Functions

Table 12.2 shows the Connectionless-mode Network Service primitives provided by this protocol. The underlying connectionless-mode service, very similar to the service primitive in Table 12.2, may be obtained either directly from a connectionless-mode real subnetwork in the way specified in this standard, or indirectly through the Subnetwork Dependent Convergence Function (SND CF) or Protocol (SND CP) over a connection-mode real subnetwork, as described in DIS 8648, Internal Organization of the Network Layer.

The types of functions provided by this protocol are summarized in Table 12.3. Type 1 functions are required for all implementation. Type 2 and 3 functions are optional. If Type 2 function is selected in a PDU but not implemented locally, then the PDU is discarded, and an Error Report PDU is generated and forwarded to the originating network-entity. If Type 3 function is selected but not locally implemented, it is processed just like not selected.

12.2.2 PDU Structure Specification

The Protocol Data Unit (PDU) structure specified in this standard is shown in Figure 12.1. It is divided into four parts: the fixed part, the address part, the segmentation part, and the options part. The data portion follows the options part.

Table 12.1 IS 8348: Connection-mode Network Service Primitives

| Phase | Service | Primitive |
|------------------|---------------------------|--|
| NC Establishment | NC Establishment | N-CONNECT request N-CONNECT indication N-CONNECT response N-CONNECT confirm |
| Data Transfer | Data Transfer | N-DATA request N-DATA indication |
| | Receipt-Confirmation* | N-DATA-ACKNOWLEDGE request N-DATA-ACKNOWLEDGE indication |
| | Expedited data transfer * | N-EXPEDITED-DATA request N-EXPEDITED-DATA indication |
| | Reset | N-RESET request N-RESET indication N-RESET response N-RESET confirm |
| NC Release | NC Release | N-DISCONNECT request N-DISCONNECT indication |

* Optional

Table 12.2 DIS 8473: Connectionless-mode Network Service Primitives

| Primitive | Parameters |
|---|--|
| N-UNITDATA.request N-UNITDATA.indication | NS-source-address, NS-desti-address, NS-quality-of-service, NS-userdata |

Table 12.3 DIS 8473: Connectionless-mode Network Service Functions
=====

Type-1:

PDU composition and decomposition;
Header format analysis and PDU header error detection;
PDU lifetime control;
Route and forward PDU;
Segmentation and reassembly;
Discard PDU;
Error reporting

Type-2:

Security;
Complete source routing;
Complete route recording

Type-3:

Partial record routing;
Partial route recording;
Priority;
QoS maintenance;
Congestion notification;
Padding

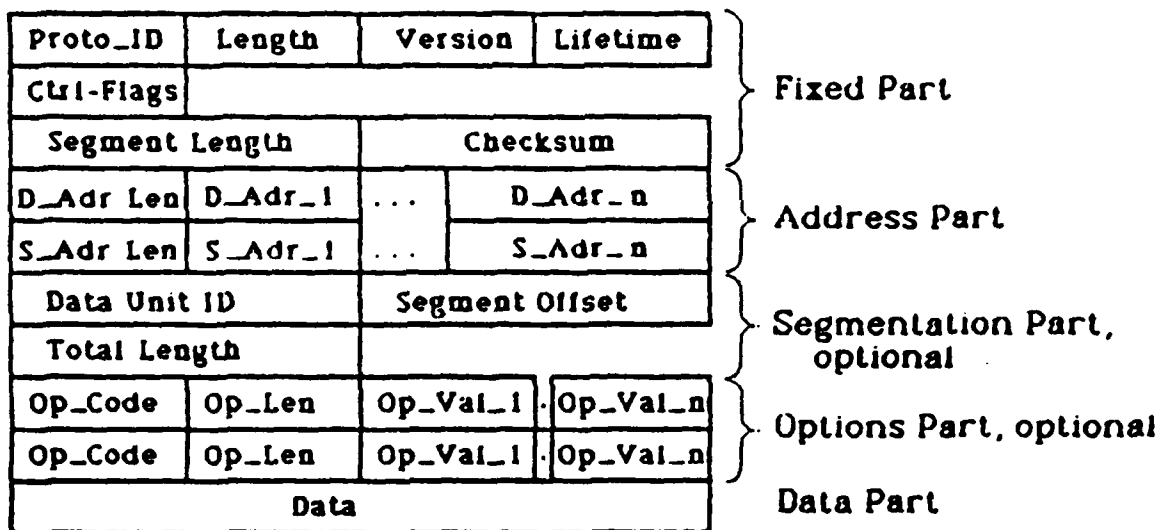


Figure 12.1 DIS 8473: PDU Structure

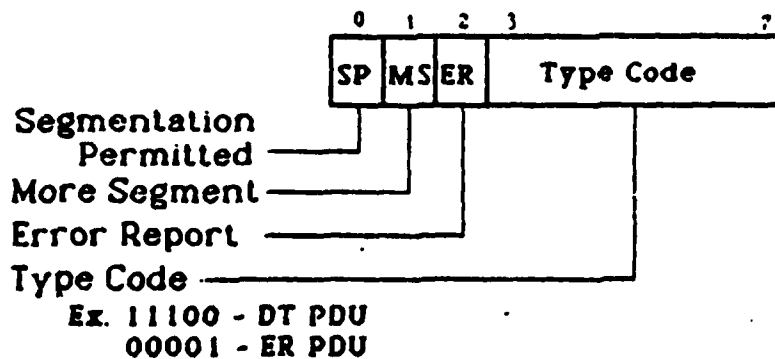


Figure 12.2 DIS 8473: Control Flags

Network Layer Protocol Identifier (1 Octet):

1000 0001: Network Layer protocol as ISO 8473
0000 0000: Inactive Network Layer protocol subset

Length Indicator (1 Octet): The length in octets of the header. The maximum is 254.

Version (1 octet): Value 0000 0001 is for this version of the standard.

PDU Lifetime (1 Octet): The remaining lifetime of the PDU, in units of 500 ms.

Flags (1 Octet): The flag bits are defined in Figure 12.2.

PDU Segment Length (2 Octets): The entire length of the PDU in octets.

Checksum (2 Octet): It is computed on the entire header.

Destination-Address Length (1 Octet)

Source-Address Length (1 Octet): The length of following address field in octets. These values may vary according to the application.

Destination/Source Address: These are the addresses defined in ISO 8348/AD2. The lengths of the field are variable, as indicated in the "Address Length" fields.

Data Unit Identifier (2 Octets): Identifies the Initial PDU (un-segmented) and all the Derived PDU contain the same value.

Segment Offset (2 Octets): For each Derived PDU, it specifies the relative position of the data segment with respect to the start of data part of Initial PDU.

Total Length (2 Octets): Specifies the total length of the Initial PDU in octets, including both the header and data.

For each option, it includes option-code, option-length, and option-value three fields.

Option Code (1 Octet): It specifies different options. Some example are shown in Table 12.4.

Table 12.4 Examples of the Options in DIS 8473

| <u>Option-Code</u> | <u>Length</u> | <u>Value</u> | <u>Description</u> |
|--------------------|---------------|--------------|--------------------|
| 1100 1100 | var | any | padding |
| 1100 0011 | 1 | * | quality of service |
| 1100 0101 | var | * | security |
| 1100 1000 | var | * | source routing |
| 1100 1011 | var | * | record route |
| 1100 1100 | 1 | 0-0F | priority |

Option Length (1 Octet): Specifies the length of option value in octets.

Option Value: Contains the value of the option with the length as indicated in the option-length field.

Besides, the provision of the underlying service from the subnetwork is also described in this standard.

13. THE TRANSPORT LAYER

The Transport Layer in OSI Reference Model provides transparent data transfer between its users, and relieves them from any concerns with the details for the reliable and cost effective data transfer. It optimizes the use of the available network service to provide required performance at minimum cost. The protocol defined at this layer have end-to-end significance, between correspondent transport-entities. Therefore the transport layer in OSI is end system oriented, and the transport protocols operate only between OSI end systems.

13.1 TRANSPORT SERVICE DEFINITION (IS 8072)

This standard defines the Transport Services in the OSI Reference Model, and the Transport Service primitives with associated state transition.

13.1.1 Transport Service (TS)

The transport service provides for the transparent, reliable data transfer between session entities. Transport services are:

- 1) Transport-Connection (TC) establishment and release in a synchronized manner:

The Transport Service utilizes an addressing system (TSAP) to allow users to refer unambiguously to one another.

It has end-to-end significance.

User can, at the TC establishment time, request, negotiate and agree on a certain quality of service (QoS).

Reset the TC to predefined state.

- 2) End-to-end reliable data transfer:

Data transparency. Data transferred are not restricted for the content, format, coding, structure, or meaning.

Flow control.

Expedited data transfer.

- 3) Quality of Service Selection:

TC establishment delay;
TC establishment failure probability;
throughput;
transit delay;
transfer failure probability; and
residual error rate which is defined as

$$RER = \frac{N(\text{lost}) + N(\text{error}) - N(\text{extra})}{N(\text{total})}$$

TC resilience;
TC release delay;
TC release failure probability;
TC protection;
TC priority.

13.1.2 Transport Service Primitives

Table 13.1 gives a list of Transport Service (TS) primitives in different phases. The allowed sequence of TS primitives with the state transition is shown in Figure 13.1.

13.2 TRANSPORT PROTOCOL SPECIFICATION (IS 8073)

This standard specifies the protocol for the connection oriented transport services.

13.2.1 Transport Layer Functions

Generally speaking, the transport layer should provide the TS users with following functions:

- 1) Assignment of the transport connections to network connections, either existing one or newly created one, with respect to:

- Resynchronization
- Reassignment after failure
- Splitting and recombining
- Multiplexing and demultiplexing

- 2) Connection establishment, with the respect to:

- Connection refusal

- 3) Transport Protocol Data Unit (TPDU) transfer, with respect to:

- Data TPDU numbering
- Resequencing
- Retention until acknowledgement of TPDUs
- Retransmission on time-out
- Expedited data transfer
- Segmenting and reassembling
- Concatenation and separation
- Association of received TPDUs with TC
- Treatment of protocol errors
- Explicit flow control
- Checksum

- 4) Normal release of TC, with the respect to:

- Frozen references

Table 13.1 IS 8072: Transport Service Primitives

| Phase | Service | Primitive |
|------------------|---------------------------|-----------------------------|
| TC Establishment | TC Establishment | T-CONNECT request |
| | | T-CONNECT indication |
| | | T-CONNECT response |
| | | T-CONNECT confirm |
| Data Transfer | Data Transfer | T-DATA request |
| | | T-DATA indication |
| | Expedited data transfer * | T-EXPEDITED-DATA request |
| | | T-EXPEDITED-DATA indication |
| TC Release + | TC Release | T-DISCONNECT request |
| | | T-DISCONNECT indication |

* Optional

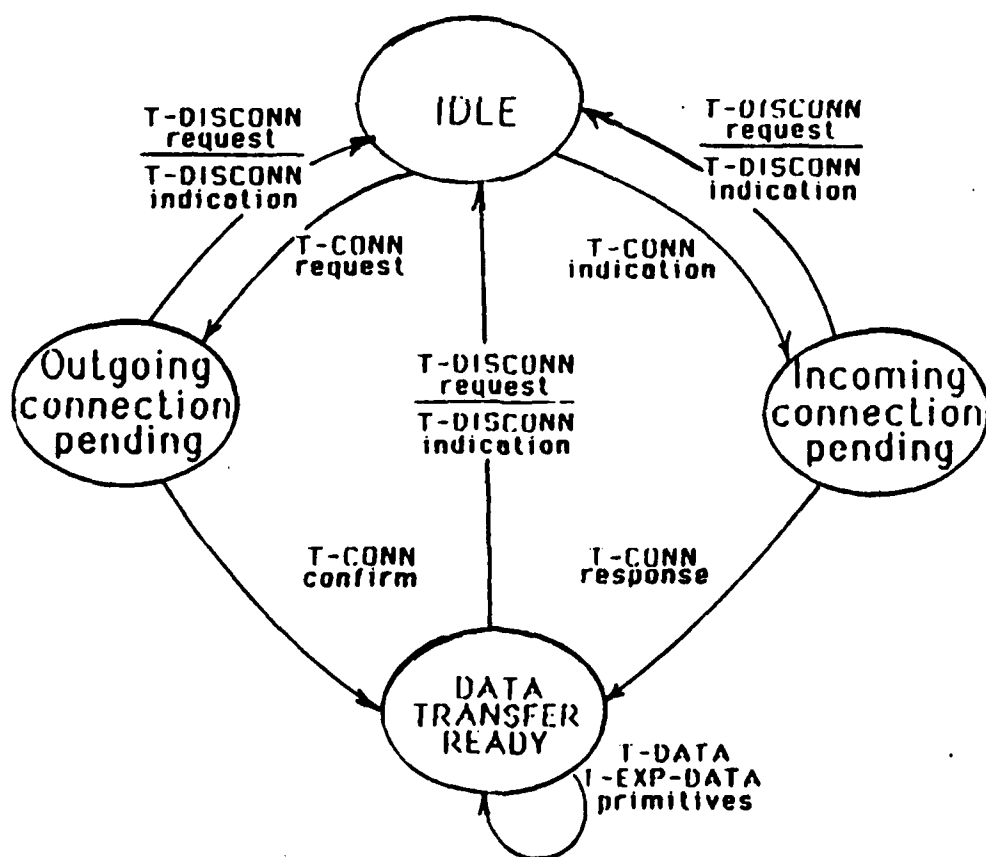


Figure 13.1 State Transition with Possible Allowed TS Primitives

5) Error release, with the respect to:

Inactivity control

13.2.2 Transport Protocol Classes

The IS 8073 standard defines five classes of transport connections with different level of functionalities. It is assumed to use three underlying choices of network connections:

- Type A: with acceptable residual error rate and acceptable rate of signaled errors;
- Type B: with acceptable residual error rate but unacceptable rate of signaled errors;
- Type C: with unacceptable residual error rate.

Five classes of transport connections are specified based on on three classes of network connections:

- Class 0: simple class
 - the simplest type transport connection,
 - compatible with CCITT T.70 for teletex terminal,
 - use type A network connections;
- Class 1: basic error recovery class
 - basic transport connection with recovery from network disconnect or reset,
 - use type B network connections;
- Class 2: multiplexing class
 - multiplexing several transport connections onto a single network connection, with/out explicit flow control,
 - use type A network connections;
- Class 3: error recovery and multiplexing class
 - characteristics of class 2, plus recovery from network disconnect or reset,
 - use type B network connections;
- Class 4: error detection and recovery class
 - characteristics of class 3, plus detection and recovery from errors of low grade service,
 - use type C network connections.

The use of classes, as well as options for those functions within classes, is negotiated during connection establishment.

13.2.3 TPDU Structure Specification

13.2.3.1 TPDU General Structure

The structure of the Transport Protocol Data Units (TPDUs) can be divided into four parts, as shown in Figure 13.2.

Length Indicate (LI, 1 Octet): The length of the header in octets.

Fixed Part: Contains frequently occurring parameters, such as TPDU code, etc. The format and the structure of this part is different for different TPDUs.

Variable Part: Contains less frequently used information. It has the structure as described in Figure 13.3.

Following section will explain some of the TPDU structures and field definitions as examples.

13.2.3.2 Connection Request (CR) and Connection Confirm (CC)

The structures of the Connection Request (CR) and the Connection Confirm (CC) TPDUs are shown in Figure 13.4.

| | |
|---------|--|
| CDT | -- Initial credit allocation, 0000 for Class 0,1 |
| DST-REF | -- Reference for the Destination transport entity, zero for CR TPDUs |
| SRC-REF | -- Reference for Source (initiating) transport entity |
| CLASS | -- Bit 8-5 (left) defines the preferred class; Bit 2 indicates the "Extended Format"; Bit 1 indicates no use of explicit flow control in class 2 |

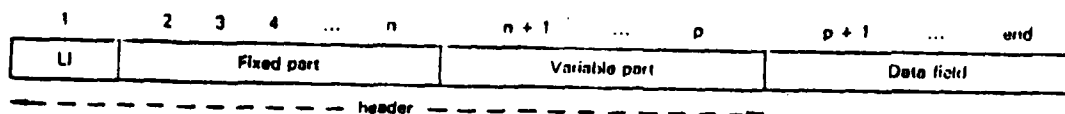


Figure 13.2 TPDU Structure

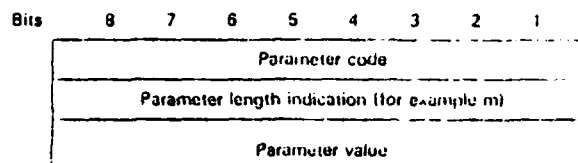


Figure 13.3 The Structure of TPDU Variable Part

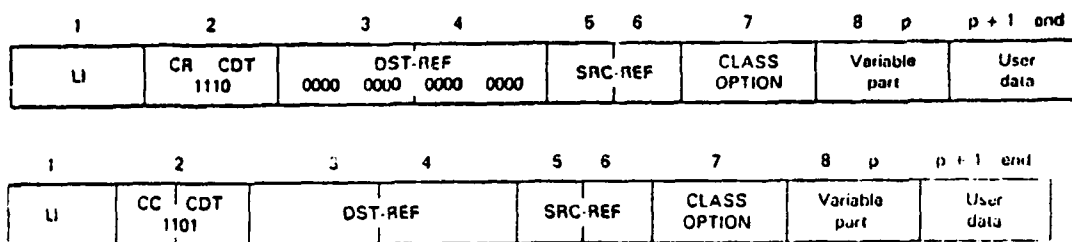


Figure 13.4 Structure of Connection Request(CR)/Confirm(CC) TPDUs

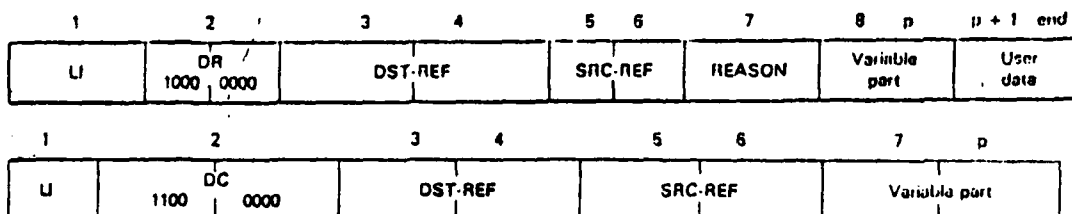


Figure 13.5 Structure of Disconnection Request(DR)/Confirm(DC) TPDUs

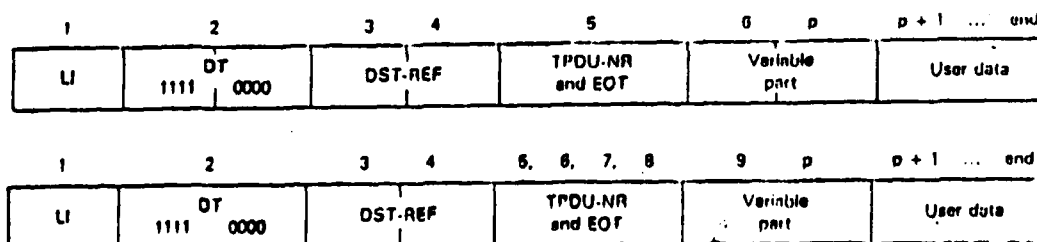


Figure 13.6 The Structure of Data (DT) TPDU

13.2.3.3 Disconnection Request (DR) and Disconnection Confirm (DC)

The structures of the Disconnection Request (DR) and Disconnection Confirm (DC) are shown in Figure 13.5.

REASON -- It defines the reason for disconnecting the transport connection

13.2.3.4 Data (DT)

The structure of Data (DT) TPDU is shown in Figure 13.6.

TPDU-NR -- TPDU Sequence number

EOT -- The end of TPDU

The second structure shown in the figure has an extended format in YR-TU-NR.

13.2.3.5 Acknowledge (AK)

The structure of Acknowledge (AK) TPDU is shown in Figure 13.7.

YR-TU-NR -- The sequence number of next expected DT TPDU.

13.2.3.6 Expedited Data (ED) and Expedited Acknowledge (EA)

The structures of Expedited Data (ED) and Expedited Acknowledge (EA) are shown in Figure 13.8. ED and EA have very similar structure compared to the one of DT and AK.

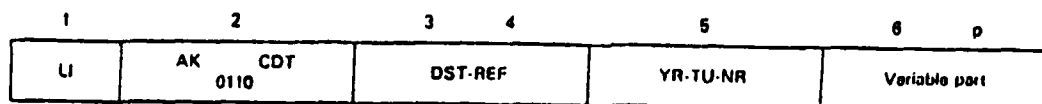


Figure 13.7 The Structure of Acknowledgement (AK) TPDU

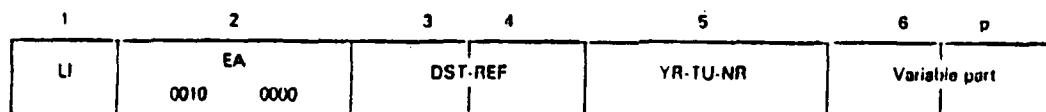
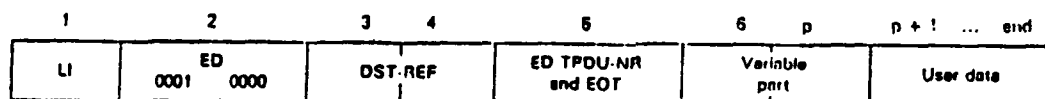


Figure 13.8 Structure of Expedited Data(ED)/Acknowledgement(EA) TPDUs

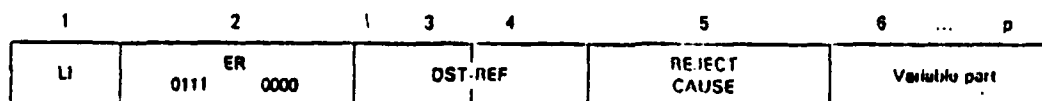
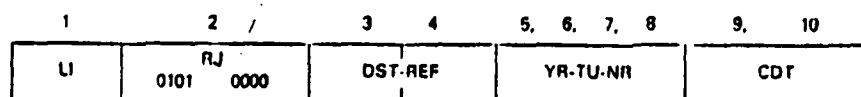


Figure 13.9 The Structure of Reject (RJ) and Error (ER) TPDU

13.2.3.7 Reject (RJ) and Error (ER)

The structures of Reject (RJ) and Error (ER) TPDUs are shown in Figure 13.9. The structure for Reject is straight forward. The "Reject Cause" in the Error TPDU gives an explanation of the reason for the error condition.

13.2.4 TC State Transition

Since the transport protocol defined in this standard is connection oriented, the state transition specified here also includes the part that deals with the network connections. The complete state transition is so complicated that it has to be explained in a state table, not in a graphic format. On the other hand, in our case, the connectionless-mode network services are used instead of connection-mode, and the state transition for the transport protocol is simpler. This will be described in next section.

14. THE SESSION LAYER

The reason for the Session Layer to be briefly described in this section is the incompatibility between the DDN TCP and ISO TP protocols. In the OSI Reference Model, the Session Layer provides necessary services for their users to organize their dialogue and to manage their data exchange. It takes full care of the session-connection establishment and release in a synchronized manner. So the Transport Layer does not repeat the function for the synchronized release of transport connection. On the other hand, in the DDN Internet architecture, there is no explicit session layer, TCP is taking the full charge for the transport connection establishment and release in the synchronized manner. If the TCP user at one side issues the CLOSE command to disconnect the TCP connection, the TCP user at the remote side is notified, the data exchange may be continued until the remote TCP user issues a CLOSE command. Both side of TCP connection are well-synchronized in this method. To match the services and functions between DDN TCP and ISO TP, the normal connection release function from the Session Layer are examined here.

14.1 SESSION LAYER SERVICES

The Session Layer provides the services necessary for co-operating presentation-entities to organize and synchronize their dialogue and to manage their data exchange.

- 1) establishment and release of session-connection mapped onto the transport-connection;
- 2) session-connection synchronization;
- 3) normal data exchange;
- 4) expedited data exchange which is free from token and flow control constraints;
- 5) quarantine service by which an integral number of session-service-data-units sent on a session-connection are not available to the receiving presentation-entity until explicitly released by the sending presentation-entity;
- 6) interaction management, to allow
 - a) two-way-simultaneous (TWS);
 - b) two-way-alternate (TWA); and
 - c) one-way interaction.
- 7) exception reporting.

To support the services, following functions are performed within the Session Layer:

- 1) session-connection to transport-connection mapping;
- 2) session-connection flow control;
- 3) expedited data transfer;
- 4) session-connection recovery;
- 5) session-connection release; and
- 6) Session Layer management.

14.2 SESSION SERVICE PRIMITIVES

Table 14.1 gives a list of Session Service primitives.

The Session Service primitives for the Session connection release will be further discussed in the transport gateway design.

Table 14.1 Session Service Primitives

| ===== | |
|---------|-----------|
| Service | Primitive |
| ----- | |

Session Connection Establishment Phase:

Session-connection S-CONNECT request/indication/response/confirm

Data Transfer Phase:

| | |
|---------------------|--|
| Normal data xfer | S-DATA request/indication |
| Expedited data xfer | S-EXPEDITED-DATA request/indication |
| Typed data xfer | S-TYPED-DATA request/indication |
| Capability data | S-CAPABILITY-DATA req/indi/response/confirm |
| Give tokens | S-TOKEN-GIVE request/indication |
| Please token | S-TOKEN-PLEASE request/indication |
| Give control | S-CONTROL-GIVE request/indication |
| Minor sync-point | S-SYNC-MINOR req/indi/response/Confirm |
| Major sync-point | S-SYNC-MAJOR req/indi/response/confirm |
| Resynchronize | S-RESYNCHRONIZE req/indi/response/confirm |
| P-exception report | S-P-EXCEPTION-REPORT indication |
| U-exception report | S-U-EXCEPTION-REPORT request/indication |
| Activity start | S-ACTIVITY-START request/indication |
| Activity resume | S-ACTIVITY-RESUME request/indication |
| Activity interrupt | S-ACTIVITY-INTERRUPT req/indi/response/confirm |
| Activity discard | S-ACTIVITY-DISCARD req/indi/response/confirm |
| Activity end | S-ACTIVITY-END req/indi/response/confirm |

Session Connection Release Phase:

| | |
|-----------------|-------------------------------------|
| Orderly release | S-RELEASE req/indi/response/confirm |
| U-abort | S-U-ABORT request/indication |
| P-abort | S-P-ABORT indication |

14.3 ISO STANDARDS FOR THE SESSION LAYER

The ISO 8326 standard is for the basic connection oriented session service definition.

The session services defined in this standard are performed by ISO 8327 standard: the Basic Connection Oriented Session Protocol. The session protocol is specified with respect to:

- 1) use of the transport service;
- 2) procedure elements related to Session Protocol Data Units (SPDU);
- 3) structure and encoding of SPDUs.

PART IV. PROTOCOL CONVERSION FROM TCP TO ISO-TP

Based on the summary over the DDN TCP/IP protocols and the ISO/OSI protocols given in previous two chapters, this section will give further discussion over the matter of matches and mismatches between the two protocol suites. The functionalities are studied for the protocol conversion tasks between TCP and ISO-TP. The methodology approaches with the protocol conversion are discussed. The rule-based general protocol conversion at the transport/network layer is concluded from the discussion.

For the gateway system design, the protocol conversion tasks are divided into subtasks, implemented by modules. The gateway specification is carefully developed with regards to easiness of understanding, and avoiding over-specification with unnecessary details. The specification is developed using a formal specification language, called ESTELLE.

15. INCOMPATIBILITY CONCERNS

The discussions in this chapter are concentrated on the different aspects of the incompatibilities, the comparison of the service provided, and the study of each incompatible items between TCP and ISO-TP. The incompatibilities between the IP and the ISO-IP are not studied here. The handling of the incompatibilities between IP and ISO-IP can be described as one to one static PDU translations, which will be discussed in the design.

15.1 DIFFERENT ASPECTS OF THE INCOMPATIBILITIES

From the view point of the functionalities, comparing the functions of TCP described in the beginning of the section 10 and the functions of ISO-TP described in Section 13.2.1, both of them provide very similar services. This condition is important because it implies that hard mismatches which could render gateway system inoperable to not exist.

From the view point of the Protocol Data Unit (PDU) structure, they are similar with suitable differences. Translation of PDUs is needed in the gateway. But this translation can be viewed mainly as a protocol-dependent part of the gateway task. It

implies that those fields in the PDU related only to one particular protocol should be handled by the protocol-dependent submodule. One example is that the checksum field for different protocols can be processed separately. On the other hand, those fields in the PDU which have the common meaning for both gateway protocols but with different format should be translated cooperatively by the protocol-dependent and protocol-independent submodules. Examples of the operation codes and the control flags should be interpreted in this way.

From the view point of the interfaces between protocol layer and the service user, it has no significance here because the service user is not considered here. One example to explain this point is that the transport gateway considers only the interoperability between transport protocols, not the interface to the transport service user. The same kind of upper layer protocol is assumed in the case. The interface design in this gateway will be aimed on the interfaces between the submodules.

From the view point of the internal state transition and the peer entity interaction, conversion is a more complicated matter. One example is that ISO-TP allows the Connection Request TPDU to carry user's data, while DDN TCP does not support this option. There is no one-to-one translation to resolve the difference. There is no method to attack this problem. It can be simply handled by restricting ISO-TP user to use the option to emphasize the usage of common-subset functions, as proposed in [GROEN 86]. The problem can also be solved in a more complicated way to have the gateway to take more responsibilities. More studies are needed in attacking this kind of problem.

15.2 SERVICE COMPARISON

To be prepared for the methodology discussion for the protocol conversion, the comparison between the TCP and the ISO-TP is summarized in the Table 15.1. Further technical detail about those difference will be studied in following sections.

15.3 CONVERSION TASKS IN CONSIDERATION

In this section, the conversion tasks and the methods used for the protocol conversion will be discussed item by item. Each item represents an entry of incompatibility between TCP and ISO-TP as listed in Table 15.1.

Table 15.1 Service Comparison between TCP and ISO-TP

| Function/Event | ISO-TP | TCP |
|------------------------------------|----------------------------------|--|
| <u>TC Establish Phase:</u> | | |
| Connect collision | Two TC established (one way) | One TC established for given pair of socket |
| Addressing | Any possible structure | Static length |
| Expedited data | Yes, negotiable by user | No, has URGENT signal |
| QoS | Loosely defined, multifunctional | well-defined subset of ISO |
| User data | Limited length | No |
| <u>Data Transfer Phase:</u> | | |
| User data | Octet stream | Octet stream, may be divided into TSDUs using PUSH |
| Urgent Signal | No | Yes |
| Expedited data | Precedence over normal data | No |
| Flow control | Explicit or implicit | Explicit |
| <u>TC Release Phase:</u> | | |
| Orderly release | No | Yes |
| Abrupt release | Yes | Yes |

15.3.1 TC Establish Phase

Connection Collision. In TCP, if the TC initiator, after sending the Connection Request (CR) to a destination host, receives a CR from the destination host, only one connection is going to be established, and both hosts share the connection in the communication. On the other hand, ISO-TP will try to establish two one-way connections.

In matching the difference, some researchers suggests that the ISO-TP addresses should be grouped, such as into even and odd addresses, for the outgoing and incoming calls. As far as we are concerned, it is not good idea to impose this kind of restriction on the addressing scheme. First, by examining the TCP/IP addressing scheme and the predefined TCP port addresses, it is obvious that most of the ports are defined as passive servers for various applications. It means that it is not likely to have a high probability for the connection collision. This should be true for the ISO-TP case. Secondly, if the ISO-TP host is the first CR initiator while the TCP host initiates the colliding CR, it can be absorbed by the gateway submodule at the TCP side without notifying the ISO-TP side. If the ISO-TP host initiates the colliding CR, the ISO-TP host must explicitly provide the calling address within ISO-TP addressing allowance. With this method, the connection collision can be solved by special functions in the gateway submodules.

Addressing. TCP allows only static length, fixed format port addresses, while ISO-TP allows any possible structures to be used in the addressing scheme. To resolve the incompatibility, restrictions have to be imposed on the ISO-TP users that only TCP-compatible addressing formats are allowed while calling TCP users. This requirement should be reasonable because whether the ISO-TP user is calling TCP host or calling through TCP node, the TCP address has to be used, either by calling (TP) user or translated by the gateway.

Expedited Data. ISO-TP provides services for transferring expedited data, negotiated at the beginning of connection establishment between users by selecting different Transport Service classes. TCP does not support the expedited data transferring, but it has URGENT signal used for transferring URGENT data. This difference will be discussed as one of the points in the data transfer phase.

Quality of Service. Quality of Service (QoS) is loosely defined by multifunctional control parameters in ISO-TP. In TCP, it is a well-defined subset of ISO QoS. For the same reason,

restrictions will be imposed on the ISO-TP users to use only those QoS compatible with the TCP QoS.

User Data. In the ISO-TP, user data can be contained in the Connection Request TPDU with limited length. But it is not allowed in the TCP in Connection Request. This incompatibility will cause problems if the TPDU-to-TPDU translation technique is used in the gateways. In the other case, if TPDU-to-TPDU translations not used, a gateway submodule can separate the user data from the CR TPDU, store the data temporally, and compose special data TPDUs to transfer them after the connection is established.

15.3.2 Data Transfer Phase

User Data. Basically, both TCP and ISO-TP transfer user data as octet streams. In TCP, user data may be divided into segments by using PUSH signal. It is very similar to the concatenation function of the ISO Transport Layer.

Expedited data. ISO-TP provides the user the service to transfer expedited data, with precedence over normal data. TCP does not provide service, but it allows a user to use the URGENT signal to send urgent data. Basically, they are different because URGENT data in TCP allows the transfer of control information along with the user data, with or without higher priority, depending on the interpretation of the higher layers. The expedited data in ISO-TP is a measure to assure the correctness of the data transfer. It is possible to use the URGENT data of TCP network for the Expedited Data service from the ISO-TP network in the following manner. When the gateway submodule receives the Expedited Data from the ISO-TP host, it will add a predefined special segment of URGENT data to the TCP TPDU to be transferred to the destination TCP host. A Special interface at the destination host will pick up the message in the URGENT data part of the TPDU, and convey it to be the Expedited Data before sending it to the higher layer ISO software. It can be considered in the same way if the DDN application package runs in the ISO network.

Flow control. In TCP, the flow control is explicit. While in the ISO-TP, the flow control could be explicit or implicit. There are two ways to solve the problem: restrict the ISO-TP users to use explicit flow control only; or absorb the implicit flow control at the gateway submodule.

15.3.3 TC Release Phase

Orderly release. TCP provides the service for the orderly release of the connection. If the user at one end sends a CLOSE to close the connection, the TCP at the other end will notify the user, continue with data transfer if necessary, wait for the user to issue the CLOSE, and then close the connection. In ISO standard, the orderly release is considered a task for the session layer protocol. So the ISO-TP does not support the orderly release function. One of the approaches to solve the problem is to add a sublayer above the ISO-TP to include the orderly release the connection. Another approach is to resolve the incompatibility in the gateway submodule. If the TCP host issues the CLOSE request, the gateway will produce a Disconnect Request to the ISO-TP host, and continue the orderly release with the TCP host as if the orderly release has been done with the ISO-TP host. The ISO upper layers using the TCP service should be clear about this difference, and the Orderly Release is still required at the Session Layer in order to call the ISO host. The Orderly Release at the Transport Layer will be performed after the Session Layer has performed the Orderly Release and called the Transport Layer for the CLOSE.

16. CONVERSION METHODOLOGY

This section describes approaches for protocol conversion between TCP and ISO-TP. Each method has its merits and disadvantages, related to cost and performance.

16.1 CONVERSION TASKS IN GENERAL

For the purpose of protocol definition and specification, protocols are usually defined in terms of functional descriptions, procedural descriptions (operational model), structural descriptions (PDU structure), and interface descriptions.

For the purpose of protocol conversion analysis, the protocol machine can be divided into three functioning modules: interface, peer, and control protocols. The interface protocol takes care of interaction between the layer protocol with service users and underlying layer protocol support. The peer protocol is in charge of interaction between the local and remote peer entities at the same layer. The control protocol manages the internal state transition of the protocol machine. Accordingly, the protocol conversion tasks are studied with respect to these three aspects. The interface to the service user is of no importance here because the assumption that the upper layer protocols above this converted layer are the same. There should be no change

made in the interface to the underlying supporting protocol.

The peer protocol conversion includes the protocol data unit translation. For those data fields which is only related to one side protocol in the conversion, they should be processed locally to that protocol. Other data fields also need to be translated in certain strategies. The control protocol conversion is of much more complicated matter which will be discussed in more details later.

16.2 DIRECT CONVERSIONS

In the first serious attack of the protocol conversion problem at the transport layer between DDN TCP and ISO-TP was reported by Groenbraek in [GROEN 86]. In this treatise, the direct conversion method is used. Based on the study of the protocol differences, a state-to-state, PDU-to-PDU conversion method is used. The advantage of this approach is that the conversion procedure looks straight forward. It contains the direct conversion of all states from one protocol to another. However, this approach imposes disadvantages on the implementation.

- 1) Unnecessary repetition of similar details;
- 2) No consideration to the extension of this work to other protocols;
- 3) Imposes heavy restrictions upon users which results in a critical drawback to performance. This point will be further discussed below.

16.3 RESTRICTION-UPON-USER APPROACH

This approach has been discussed in several papers in [GREEN 86], [GROEN 86], etc. It was recognized in these papers that the first step in the protocol conversion is to find common set of the services, and then convert the functions related to these services. The principle behind this approach is obvious. The conversion is performed between the services of the users.

This approach imposes two serious disadvantages. One of them is the restriction upon users. By the conversion only over the common set of the services, it restricts the users from using those services which are not in the common set of services. Since it is impractical to modify the communication software at upper layers on all the hosts, it puts the burden on those users using the service through gateways. Another disadvantage is that

this approach does not consider those mismatches which need more intelligence to be solved. Some examples will be given in following section, and further discussion will be given in next chapter.

16.4 RULE-BASED METHOD

In this approach, those services with minor incompatibility problems will be solved with a little more intelligence in the gateway system. For example, TCP does not allow the Connection Request (CR) TPDU to carry any user data. In case that user data are contained in the Connection Request TPDU from ISO-TP, instead of not allowing user to do that, the gateway can divide CR into Connection Request TPDU and the Data TPDU for the TCP network. The reasonability for this approach is on the TCP side and the ISO-TP side must keep their own Sequence Number. In this way, extra data TPDU will not disturb the normal operation. The acknowledgement for the extra data TPDU will be consumed at the gateway because it does not need to be sent to the ISO-TP network. The gateway needs to keep record of the extra TPDUs it creates.

Another example is the PUSH function in TCP. The PUSH function in TCP means that when a user indicates the PUSH flag in the SEND data call, the TCP module should not wait for further user data to be concatenated for efficiency, but rather send the user data right away. This function requests only immediate delivery of the user data. It can be handled by either ignoring the PUSH flag and sacrificing a little performance, or by using other control functions such as Expedited Data in the ISO-TP network. The rule-based method can be approached so that the knowledge about the characteristics of the service and the knowledge about the way to make up the difference and to solve the incompatibility are used in handling different service functions.

16.5 MODULAR SYSTEM DESIGN

With the consideration discussed in the last section, the gateway system design should take the modular system design approach. The major point is to divide the gateway system into three parts: the protocol-dependent modules, the general purpose linker module, and the interface modules to connect them together. The superset of the service provided by different transport protocols, instead of subset of common service, should be considered. The results then are used for designing the data and control structures in the general purpose linker module. The rule-based tasks will be handled in the interface module to resolve the difference between the general purpose linker module

and the protocol-dependent modules. The details of the design will be explained in the following sections. A similar approach was followed in the testing of functional specifications of a generic gateway [MART 88].

17. FUNCTIONAL MODULES

In this chapter, the modular structure of the gateway system to interconnect the TCP/IP and the ISO/TP is discussed. The functions of each module are described based on the system design.

17.1 THE MODELS OF THE PROTOCOL CONVERSION

This section contains the models for protocol conversion. The two models used include the Message Translation Model and the State Translation Model.

17.1.1 The Message Translation Model

The Message Translation Model is shown in Figure 17.1. This model deals with the message translation, which corresponds to the handling of the PDU subprotocol and the interface subprotocol. The handling of the PDU subprotocol is obvious in this case. All the PDUs from the local network, say P', are temporary stored in the packet buffer, and processed in the local-network interface module to check the validity. The local-protocol dependent parts of P' are stripped off and the original PDU P' are translated into P, depending on the design. Examples are the correctness of the checksum, the validity of the address, the sequence numbers and window parameters, and the legitimacy of the packet control commands with regard to the FSM state in the protocol module. A record of the connection control information of local-protocol dependent parts will be kept in the local interface module. The data and the control information with common interests will be passed over to the linker module, where the control information is kept for reference for follow-on communications. The data and the necessary control information, in the format of P, will be then relayed to the remote interface module. In the remote interface module, similar work in the local module will be reversed to make up the PDU" from P, by adding in the protocol dependent control information. The PDU P" will then be sent through the service provided by the underlying layer to the remote network. Whether the packet will be kept in the buffer or not until acknowledgment is received is completely

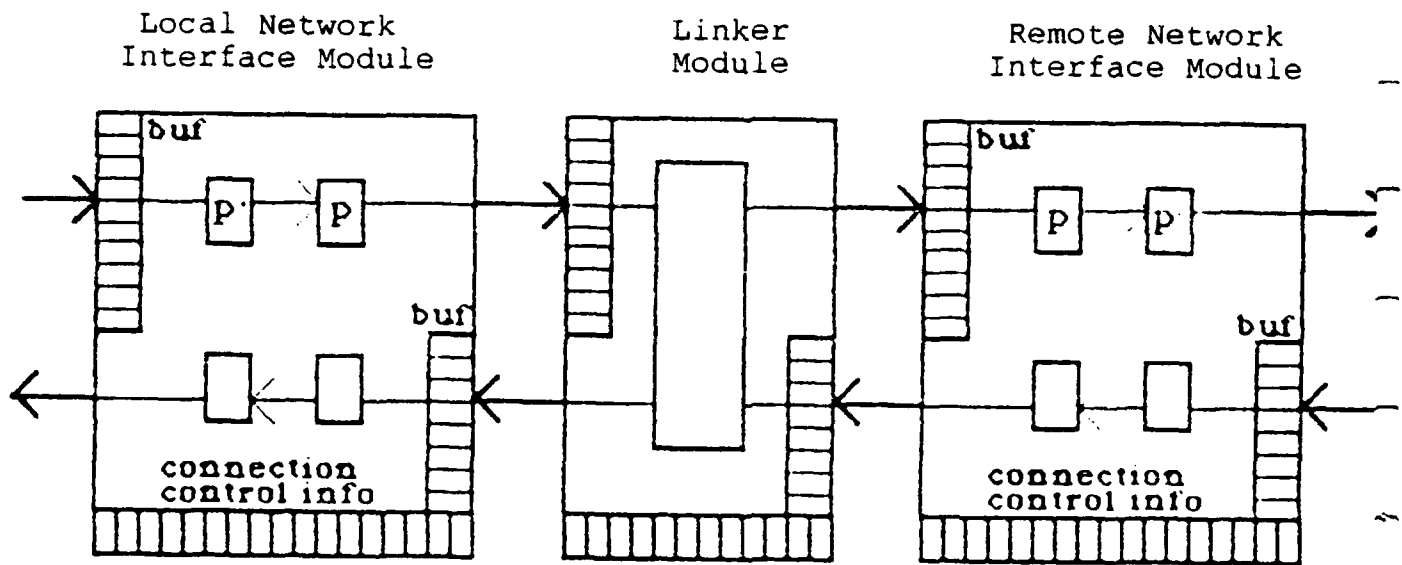


Figure 17.1 The Model of Message Translation in Gateway

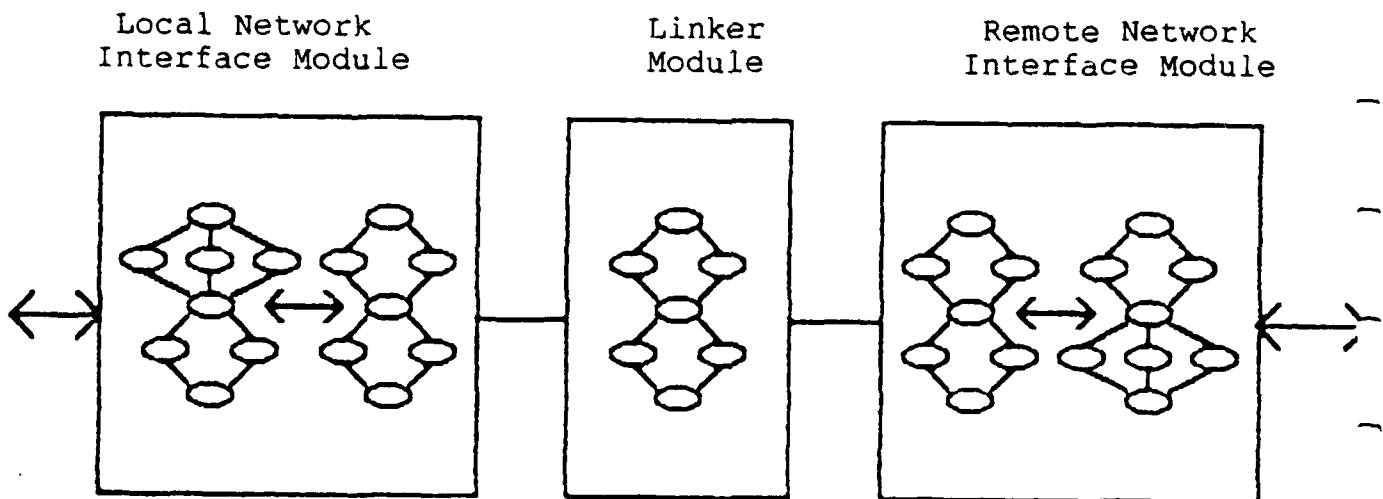


Figure 17.2 The Model of State Conversion in Gateway

dependent on the gateway strategy.

The handling of the interface subprotocol is done in the process of the communication. The interface subprotocol keeps the interface compatibility between this layer and the underlying layer. The interfaces between the local module and the linker and remote modules are implementation dependent. Though, the integrity of the service interface between this layer and the upper layer should still kept in consideration.

17.1.2 The State Conversion Model

Another model of the gateway task is shown in Figure 17.2. This model deals with the state conversion, which corresponds to the handling of the internal state transitions and the peer entity interaction.

The local and remote protocol-dependent modules in this model plays two major functions. One function is to maintain the internal state transitions as defined by its own protocol. The other function is to convert the state defined in the local protocol into the common state handled by the linker module, and vice versa. The set of common states is the super set of all states in the protocols. The linker module in this model is merely an interface, it defines the super set of the common state. It records the state of each communication channel during its operation using this super set of state. Since each set of states of individual protocol is the subset of the common state set, the difference between individual subset and the common set is made up of protocol-dependent modules. If there exists a one-to-one relationship between the pair of local protocol states and the common states, only the name translation is needed. If there is no such one-to-one relationship between the pair of states, the protocol-dependent module will be in charge of the translation between the subset states and the common set states. All these state processing should be confirmed with the peer entity interaction specification of the local protocol with respect to the local network.

17.2 SYSTEM STRUCTURE

In this section, the gateway layer and the system designs are discussed based on the basic models described above.

17.2.1 The Layer Design

In the gateway architecture designed here, the structure of each layer in the gateway is composed of both models discussed in last section. The common linker module and the protocol-dependent modules are in charge of both the message translation and the state conversion at the same time.

As shown in Figure 17.3, the linker module defines and uses the set of common states and the common data structure for the communication session control and for the data packets transfer to communicate with the protocol-dependent modules. The state of the communication session and other control information are kept in record in the linker module. The data packets are relayed between the protocol-dependent modules. The protocol-dependent modules can be further divided into two submodules. One of them is the local protocol-dependent submodule which takes care of the packet validity and state legitimacy checking and the communication session status maintenance according to local protocols. The other is the interface submodule which takes care of the translation of the packet structure and the state transition between local protocol and common definition of the linker module.

The local protocol-dependent submodule takes the full responsibility of the interface subprotocol with the underlying layer, the PDU correctness checking, and the peer entity interaction with the communicating nodes in the local network. For example, it automatically establishes the lower layer connection when the connection is requested at this layer. The lower layer provides connection-oriented service. It also encapsulates and decapsulates the packets with the protocol control information of the layer, such as sequence number, window control, etc. It will send back reasonable responses and change its own state when service is requested by the other nodes in the network.

The interface submodule translates the packet data structures into the common data structure, along with the translation of the control command, options. The protocol-dependent parts of packets will be discarded in the translation. It is necessary to reduce the amount of the information to be converted to reduce the delay. On the other hand, when the data packets and the control information passed over from the linker module which are not supported by the local protocol, it is also the interface submodules responsibility to resolve the incompatibility.

17.2.2 The System Design

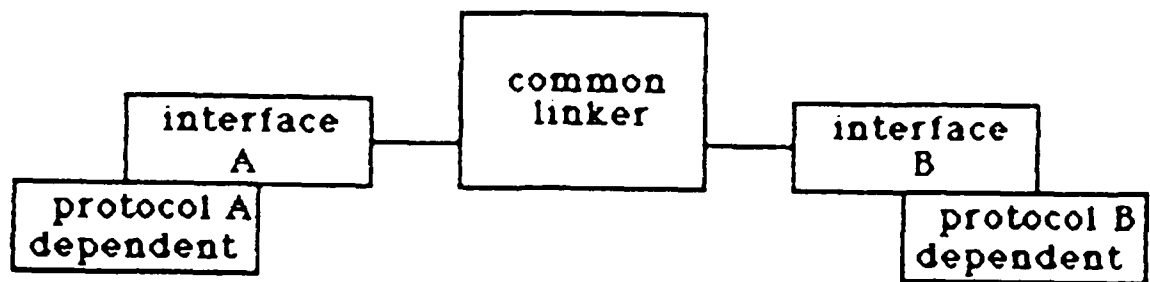


Figure 17.3 Moduled Design of the Gateway Layer

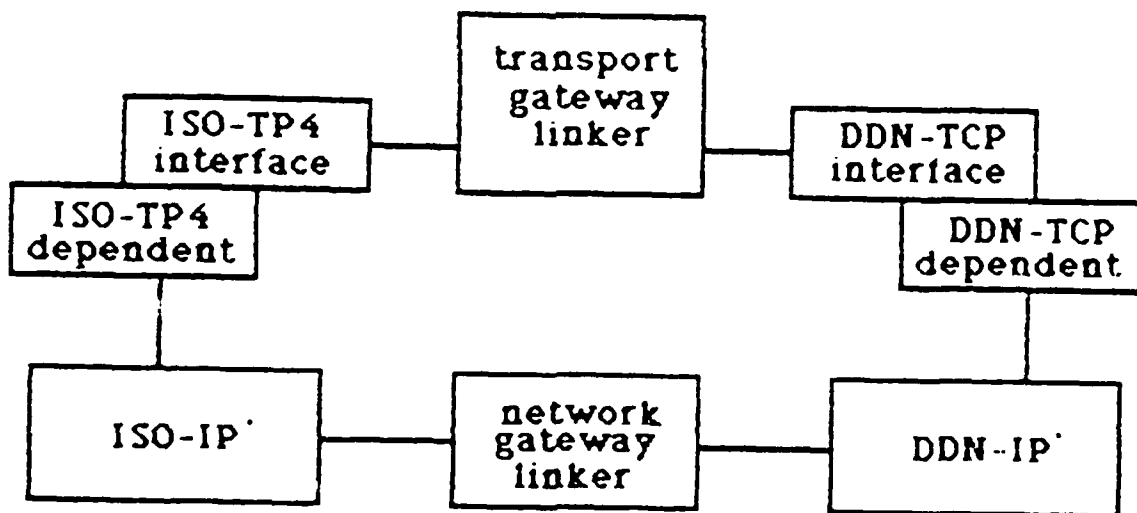


Figure 17.4 Moduled Design of the Gateway System

The Transport Gateway designed in this project is concerned with both the Network Layer and the Transport Layer, as shown in Figure 17.4. As a case study, the TCP and the ISO-TP4 with the connection-oriented reliable virtual circuit service will be considered in the transport layer, and the IP and the ISO-IP with connectionless datagram service will be considered in the Network Layer. It is possible to use only one linker module for both the Transport and Network Layers, but it is against the concept of layered architecture and modular design. So, separate linker modules are used for each layer in the case. Each linker module takes care the communication in its own layer.

Not much control information are recorded in the Network Layer linker module, because both DoD IP and ISO-IP provide the datagram service in which datagrams are not logically related to each other. On the contrary, there is more common control information in the Transport Layer linker module, such as addresses, state of the connection, etc. The data structures and algorithms are designed to reduce the amount of information to be transferred between modules.

Better modularity is achieved by allocating the queue of the incoming and outgoing packets inside the interface submodule, and having the linker module in charge of transferring packets between the interface submodules of individual local protocols. There will be one queue associated with each direction of data flow in the interface submodule. The interface submodule reads packets in the incoming buffer queue from the linker module, and deposits packets into the outgoing buffer queue to the linker module, and modifies the pointers accordingly. The linker module treats the buffer queues of all interface submodules equally. It reads packets from the outgoing buffer of one interface submodule and deposits packets into the incoming buffer of another interface submodule. Using this strategy, the gateway is capable of converting more than three sets of protocols without critical modification of the system design. More technical issues in the design will be discussed in following sections.

17.3 PROTOCOL CONVERSION IN THE NETWORK LAYER

The Network Layer of the gateway in design translates the DoD Internet Protocol (IP), referring to Chapter 7, to and from the ISO-IP protocol, referring to DIS 8473 in Section 12.2. Both protocols provide the connectionless datagram service.

17.3.1 Protocol Conversion Tasks

In the DoD IP and the ISO-IP, the following data fields and related functions are protocol-dependent. They are handled inside the protocol-dependent submodules, not translated during the communication:

| DoD IP | ISO-IP |
|-----------------|---------------------------|
| IP Version | IP Version |
| Protocol | |
| Header Checksum | Header Checksum |
| | network Layer Protocol ID |

All the other data fields listed below need to be translated and transferred to the other side in the communication:

| DoD IP | ISO-IP |
|------------------------|----------------------------|
| Internet Header Length | Length Indicator |
| Type of Service | Type Code |
| Total Length | PDU Segment Length |
| Identification | Data Unit Id |
| Flags | Flags |
| Fragment Offset | Segment Offset |
| Time to Live | PDU lifetime |
| | Source Address Length |
| Source Address | Source Address |
| | Destination Address Length |
| Destination Address | Destination Address |
| Options | Options |

Among the parameters, the Internet Header Length in DoD-IP and the Length Indicator in ISO-IP are the length of the headers in 32-bit word and byte respectively. The original parameters have no significance to the other protocol sets because the header formats are different. It should be modified to indicate the length of the option. Translation is needed between the Type of Service, the Flags, and the Options in DoD-IP and the Type Code, the Flags, and the Options in ISO-IP.

The Total Length in DoD-IP and the PDU Segment Length in ISO-IP should be adjusted according to the justification of the header length. Minor modifications are needed for the Identification, and the Fragment Offset in DoD-IP and the Data Unit Id, and the Segment Offset in ISO-IP, such as the modification on the size of the field. The time unit for the Time to Live in DoD-IP should be changed from seconds into half-seconds used in the PDU Lifetime in ISO-IP.

For the address fields, the ISO-IP is restricted to use the address formats which can be converted into the CLASS A, B, and C address formats of the DoD-IP. Translation is needed between the address format.

17.3.2 Protocol-Dependent Submodule

The protocol-dependent submodule is the front-end interface which receives and delivers packets to and from the sub-network layer of the local network. It checks the validity of the packets, records the status into the statistics, and strips off the fields with only local network significance. It should confirm with the local protocol definitions about the interface subprotocol with the lower layer and the peer entity interface subprotocol with the communicating entities in the DoD-IP and ISO-IP.

The statistics keeping should be emphasized here due to the fact that the Internet Control Message Protocol (ICMP, referring to Chapter 8) is actually implemented along with DoD-IP. ISO-IP includes some error control functions inside. The conversion of the difference is handled by the combination of the protocol-dependent and the interface submodules.

17.3.3 Interface Submodule

The translation of the data structure of packets is one of the major functions of the interface submodule. As discussed in previous sections, all the fields with data significance but in incompatible format, needed to be translated. This submodule also manages the buffer queues to be accessed by the common linker module. After the buffer queues are allocated, it should notify the common linker module about the location and the control information of the queues. The packets translated from DoD-IP to the common data structure are deposited in the outgoing queue. The packets picked up from the incoming buffer queue are translated back to the DoD-IP.

Another major function of this submodule is the translation of the DoD-ICMP packet to the ISO-IP Error Packet. This task should be carefully coordinated with the protocol-dependent submodule.

17.3.4 Common Linker Module

The tasks performed in the common linker module are rather simple. It defines the common data structures used in the communication between the network-dependent interface submodules. After initialization, it collects the control information about the Network Layer protocols. This includes the locations and the pointers of the buffer queues. The remaining tasks are checking

the buffer queues of each interface submodule when interrupts happened, relaying the packets in the buffer if the buffers are not empty.

17.4 PROTOCOL CONVERSION IN THE TRANSPORT LAYER

The Transport Layer of the gateway is designed to translate between the DoD Transmission Control Protocol (TCP) and the ISO-TP Class 4. Both protocols provide connection-oriented reliable virtual circuit service. It is clearly defined that TCP uses the services provided by DoD-IP for the underlying Network Service. The ISO Transport Protocol Specification defined in IS 8073 is based on the connection-oriented Network Services. Adjustment is needed in this case to refer to the DIS 8602, Protocol to Provide the Connctionless-mode Transport Layer Service. The case of protocol conversion between the DoD User Datagram Protocol (UDP) and the ISO-TP Class 1 could be a much simpler case of the TCP to TP4 conversion.

17.4.1 Protocol Conversion Tasks

The protocol conversion tasks for this layer includes the Transport Protocol Data Unit translation and the FSM state processing.

The following fields and related functions are protocol-dependent between TCP and TP-4 which do not need translation.

| <u>DoD TCP</u> | <u>ISO TP-4</u> |
|--------------------|-------------------------------|
| Checksum | Checksum |
| Sequence Number | Sequence Number (TPDU-NR) |
| Acknowledge Number | Acknowledge Number (YU-TU-NR) |
| | Subsequence Number |
| Window | Flow Control Confirmation |

Checksum will be added for the TPDU just before sending it to the Network Layer, and it will be checked first after receiving the TPDU from the Network Layer. Different protocols have different interpretation of the sequence numbering. The sequence number in the TCP counts the bytes of user data transferred by TCP, and the sequence number in ISO-TP stands for the numbering of TPDUs. It is more reasonable to have the protocol-dependent submodules to handle the sequence and acknowledge numbers and/or window control independently.

The other parameters have their own definitions and formats for different protocol suites, and they need to be translated between the transport entities:

| <u>DoD TCP</u> | <u>ISO TP-4</u> |
|------------------|---------------------------------|
| Source Port | Calling TSAP Identifier |
| Destination Port | Called TSAP Identifier |
| Data Offset | Length Indicator (LI) |
| Flags | TPDU Code |
| Urgent Pointer | |
| Options | Options |
| | Source Reference (SRC-REF) |
| | Destination Reference (DST-REF) |
| | Disconnect Reason (REASON) |
| | Reject Cause (REJECT CAUSE) |
| | TPDU size |
| | Version number |
| | Protection |
| | Alternative Class |
| | Acknowledge time |
| | Throughput |
| | Residual Error |
| | Priority |
| | Transit Delay |
| | Reassignment Time |

Among the parameters, the Source and Destination References in the ISO-TP should be so restricted that it can be represented by the Source and Destination Ports in TCP with the length of 16 bits. The Data Offset in TCP should reflect the length of the options. The Length Indicator in ISO-TP should reflect the length of the variable part of the TPDU. Translation is needed between the Flags and the options in TCP and the TPDU Code, and the Options in ISO-TP. The other optional control parameters provided by ISO-TP do not have the counterparts in the TCP. They should be handled under reasonable policies.

17.4.2 Protocol-Dependent Submodule

The protocol-dependent submodules interface to the Network Layer to send TPDU's to and to receive TPDU's from the local networks. It checks the validity of the TPDU's by checking the checksum and the legitimacy of the TPDU Code, records the status into the statistics, and strips off the fields with only local protocol significance. It maintains the state transition of the FSM of the transport entities. It should meet the local protocol definitions about the interface subprotocol with the Network Layer, and the peer entity interface subprotocol with the communicating entities in the other TCP and ISO-TP nodes.

17.4.3 Interface Submodule

The translation of the data structure of TPDUs and the Transport FSM state are the major functions of this submodule. As discussed in previous sections, all the fields with data significance but in incompatible format needed to be translated. The submodule also allocates and manages the TPDU buffer queues to be accessed by the common linker module.

17.4.4 Common Linker Module

The procedures executed in this module are rather direct. It collects the control information about the locations and the pointers of the TPDU buffer queues after they are initialized. The control information is used for accessing and controlling the TPDU relay. The control information about each communication session should also be maintained in the common linker module so that the supervision of the virtual circuits can be implemented.

17.5 DESIGN TOOLS

The most important thing in the communication system design is to handle the concurrence in an unambiguous way. In order to select the right tool for specifying the gateway system, the current protocol description techniques will be reviewed first.

In recent years, a lot of efforts have been put in the research of the Formal Description Techniques (FDTs). Generally speaking, they are the methods to define the system behavior without using a natural language so that the system can be analyzed and interpreted unambiguously. They are important tools for the design, analysis and specification of information processing systems so that the system descriptions can be produced in a self-contained, complete, consistent, precise, concise and unambiguous way. Two FDTs defined by ISO are ESTELLE and LOTOS.

ESTELLE is a second generation FDT based upon the extended Finite State Machine (FSM) model which is considered to be closer to human understanding of protocol. A specification in ESTELLE is comprised of a set of modules which communicate with each other. Modules are specified as extended FSMs. ESTELLE is a procedural technique. Facilities in ESTELLE consist of a set of extensions to PASCAL, specifying transitions in PASCAL, introducing

algorithm details, thereby often over-specifying and diminishing the applicability of FDT. The communication in ESTELLE is done by asynchronous message passing FIFO queue buffering.

LOTOS (Language Of Temporal Ordering Specification), on the other hand, describes the system by defining the temporal relation between events in the externally observable behavior. One of the two components deals with the description of process behaviors and interactions, based on the non-procedural predicate calculus and modified Calculus of Communicating System (CCS). The other component deals with the description of data structures and value expressions, based on the Abstract Data Type (ADT) language ACT ONE.

LOTOS can express the concurrence and the functional abstraction unambiguously. But unlike the protocol specification with the emphasis on the description of the externally observable behaviors, the gateway design are more emphasized with clear description and easy understanding of the design. Since the procedural description with state transition in FSM, like the one in ESTELLE, are closer to the human understanding, it is preferred with moduled design to the non-procedural predicate logic in LOTOS. On the other hand, the functional abstraction using rule based design will be considered as necessary to avoid over-specification. For the data abstraction, the modified ADT with less algebraic specifications but more state transition descriptions will be used so that the mechanism can be easily understood and constructed.

18. SYSTEM ARCHITECTURE AND COMMON DATA STRUCTURE

To get a better view and understanding of system and better understanding of the gateway design, we start the design from the system structure, the common data structures, and the TP-4 dependent submodule. We approach the problem in this way in order to give detailed understanding of how the transport services are provided through the internal mechanism. Then, the transport linker module, the interface submodules for both TP-4 and TCP, and the TCP dependent submodule will be designed. The modules in the network layer will be designed in the last section.

In this section, the transport gateway system structure will be described first. The data structures and module descriptions will then be designed in correct ESTELLE order. The transport gateway specification in ESTELLE is included in Appendix A.

18.1 SYSTEM ARCHITECTURE OF TRANSPORT GATEWAY SPECIFICATION

The Transport Gateway system is composed of two layers with several modules in each layer, as indicated in Figure 18.1 below.

The ISO-IP and DoD-IP dependent submodules directly communicate with local networks. All the other modules communicate with each other by exchanging messages.

One difficult problem in the approach is how to convey the network control information (Network PDU header) between the network module which receives incoming PDUs and the network module which sends outgoing PDUs. There is no such kind problem in an ordinary node because the upper layer (Transport Layer) user specifies the network control parameters for sending data when requesting the network services. The network control information in the received PDU header is decapsulated before transferring the data part to the Transport Layer. In the case of Transport Gateway, the network control information are lost when the PDUs decapsulated. Certain scheme must be worked out to overcome this problem. It is not good idea to attach the network control information with the transport layer data because it is against the layered concept. It is possible to have the network

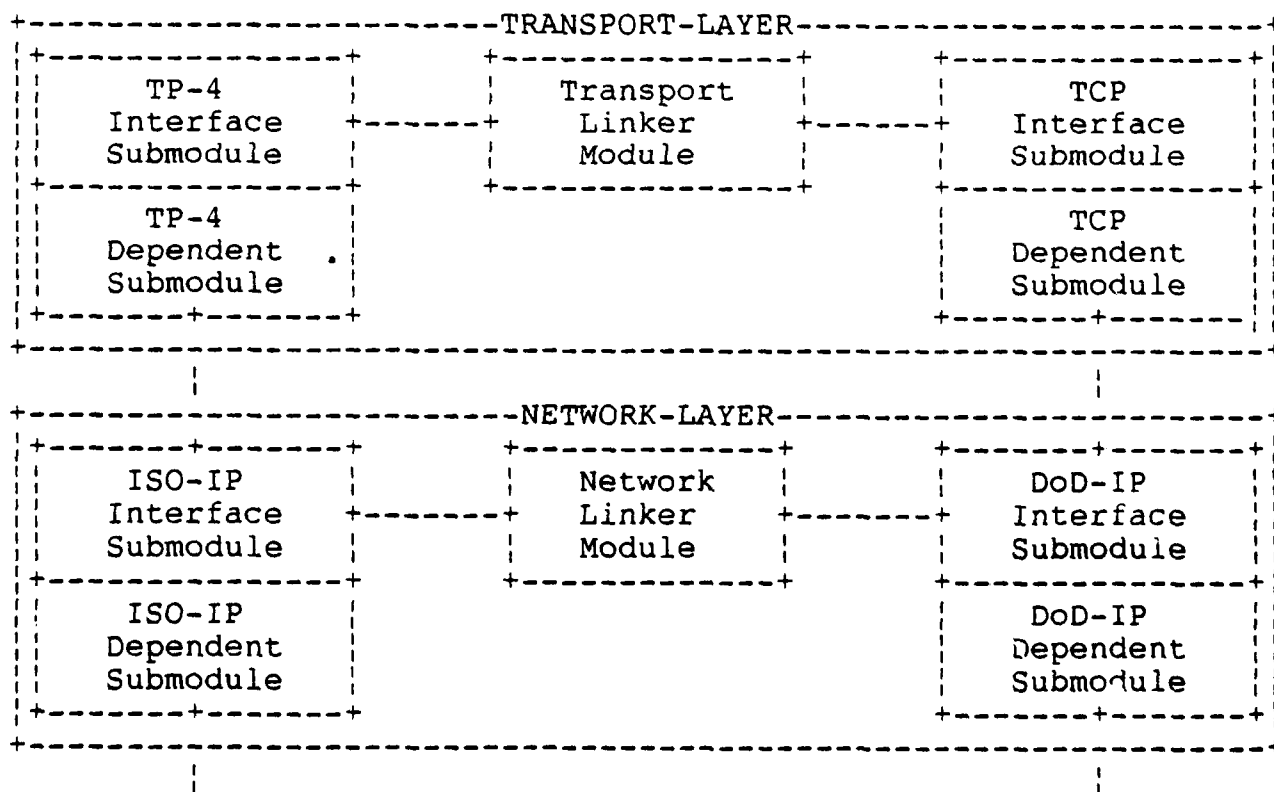


Figure 18.1 Transport Gateway System Architecture

modules to communicate directly with each other for the control information, but a one-to-one relationship has to be kept between the transport layer data and the network control information.

One approach to solve the problem is to have the TPDU carry a token so that the network module on the other side can use the token to retrieve the network control information. The token is composed of two elements: the Network Module Id to identify the initiating network and protocol type, and the Message Id to locate the particular PDU. The Network Module Id is used to identify the buffer pool for the retrieval operation. The procedure of the communication works as follow:

- a) The network module receiving the incoming PDUs will send the network control information separately to the network module on the other side, along with the local Network Module Id, and Message Id;
- b) The Network Module Id and the Message Id will also be kept in the TPDU's in two special fields;
- c) When the TPDU reaches the network module at the other side, the related network control information will be picked up by matching the Network Module Id and the Message Id.

This scheme will be reflected in the common data structure definition in next section.

18.2 COMMON DATA STRUCTURES

This section of the system design specifies the global control variables and the common data structures used in the message exchanging. The data structures defined here are for those messages exchanged between different modules at the system level. For example, the ISO-IP PDUs are exchanged between the ISO-IP module and the external world which is considered at the system level, while the interpretation of the PDUs is done inside the module. The data structure of the PDU is defined at the system level, while the interpretation of the values of the data fields is done inside the module.

The way the data structures and the interfaces are defined here is quite different from the formal protocol specifications. For the formal protocol specification, the important thing is to define the interface so clearly and unambiguously that it can be easily understood. But it cannot be done in the exactly same way in the gateway specification because it could make the design and implementation more difficult. So in some places, the data

structures and the interfaces are defined in a way of message format oriented and implementation oriented. When the underlying Network Layer service is connectionless, only one kind of data format is needed for the communication with Network Layer.

18.3 TRANSPORT GATEWAY SPECIFICATION

The commented specification for the transport gateway is enclosed in Appendix A.

19. NETWORK LAYER DESIGN

In the NETWORK_LAYER module, the common linker module discussed previously is included as a part of the NETWORK_LAYER module definition with common data structures defined and submodule interaction handled. The submodules describe the functionalities and the interfaces for ISO-IP and DDN-IP respectively.

19.1 SOME RELATED PROBLEMS

19.1.1 Handling of Segmentation

One point which is worth to mention here is that the segmentation information in the PDU header are not necessary transferred over the gateway. The segmentation information includes the flags, the Unit Id and Total Length, the Segment Offset, and the Segment Length. The segmentation is done on the TPDU basis for those TPDU with over large size. segments are reassembled back to original TPDU before sending it back to the receiving Transport entity. It is absolutely necessary because the protocol conversion is at the Transport Layer which needs the complete TPDU, not some segments of it. After the TPDU goes through the gateway, the TPDU will be segmented by the sending network entity if necessary, but it is under the complete control of that network entity. Original segmenting information has no significance here.

19.1.2 Handling of Routing

One of the important issues in the Network_Layer Gateway here is the handling of routing. In the case of Ordinary Network_layer gateway, the routing information can be achieved by packet-to-packet translation. In our case of the Transport_Layer gateway, we have the special situation that the gateway can "make up" some packets in responding to some packets just received. More complicated mechanism are needed to solve the problem:

- 1) The Common Linker will translate the routing information, but both ISO_IP and DDN_IP submodules need to keep records of the routing information;
- 2) It is necessary to encourage the usage of both source routing and record routing, so that returning routing information can be found and converted to;
- 3) In order to find the routing information for those "made up" packets, the IP submodules will always keep the routing information updated by referring to current received packet. The "made up" packets from Transport Layer will have IP address only, but the routing information will be assembled by the IP submodules.
- 4) Certain measures are required to keep the amount of recorded information down.

Following strategies are used in our design:

- 1) The normal one-to-one translated messages will be assigned with a non-zero "message_id" by the receiving IP submodule before sending to the Transport Layer and sending over through Network Layer Gateway. Using "message_id" will ease the task to assemble the data portion translated by the Transport Layer Gateway with the network routing information and some other control information.
- 2) When the IP submodule receives a PDU with zero "message_id", it knows that it is the "made up" PDU from the Transport Layer. The IP module will find the communicating pair by matching up the source and destination IP addresses, and pick up the newest routing information for that pair to be assembled into the "made up" PDU.

19.1.3 Handling of QoS Parameters

By the standard protocol specifications such as ISO-TP (ISO 8073), the Quality of Service (QoS) parameters are passed from the Transport Layer to Network Layer for service request, and from the Network Layer to the Transport Layer for service indication. But here in the case of the Transport Layer Gateway, there is no such user of the Transport Layer to specify the QoS

requirements or to accept the QoS parameters from peer entity. So, there is no need to pass those control parameters between the Transport and Network Layers, but to translate and to pass through the Common Linker at the Network Layer. This concept is reflected in the message format design and handling.

19.2 NETWORK_LAYER MODULE SPECIFICATION

The commented specification for the NETWORK_LAYER module inside the transport gateway is enclosed in Appendix A.2.

20. TRANSPORT LAYER DESIGN

In this chapter, some special problems related to the protocol conversion at the Transport Layer are discussed, followed by the specification of the Transport_Layer module of the Transport Gateway.

20.1 SOME RELATED PROBLEMS

20.1.1 Classes of Service Allowed through Gateway

Considering the fact that the DDN TCP provides the reliable end-to-end virtual circuit service which is equivalent to the CLASS-4 service of the ISO TP, it is reasonable to restrict the communication through the gateway to the same type of service, i.e. TP-4. By imposing this consideration, it means that when the gateway tries to establish the connection initiated by the TCP node. It will request the CLASS-4 service at the ISO network side. On the other hand, the gateway will accept only the connection requests from the ISO network which requests CLASS-4 services. ISO TP conformance requires that when CLASS-4 is implemented, it shall also implement the CLASS-2. The CLASS-2 is not treated here.

20.1.2 Internal FSM Modifications

As the special characteristics of the transport gateway implementation, there is no Transport Layer user and the

interface. The state transition model is no longer kept the same as the transport protocol implementation. Only the TPDUs and the peer entity interactions are kept the same as defined in the original protocols respectively. Examples of the state transitions for connection establishment and connection release for the ISO TP-4, TCP, and for the transport gateway are shown in Figures 20.1 to 20.8.

Both ISO TP-4 and DDN TCP use three-way handshaking in the connection establishment, as shown in Figure 20.1 and 20.2. Three TPDUs are equivalent between two protocols: connection request, connection confirm, and the acknowledge. The difference is that the TP-4 user of the receiving node in ISO network will receive a TCONind after the Transport Protocol Machine (TPM) receives the Connection Request, and needs to issue a TCONresp to confirm; while the TCP user of receiving node in DDN needs to issue a passive OPEN in advance to ready for incoming call. In the case of the Transport Gateway, the state transitions, shown in Figure 20.3 and 20.4, are neither the same as the one in ISO TP-4, nor the one in TCP. It always uses three state transition steps, and the transient states are different between the TP-4 initiated call and the TCP initiated call. It is critical to maintain the same message exchanging and peer entity interaction between the two end nodes in ISO network and DDN.

In the case of Connection Release, as shown in Figure 20.5 and 20.6, the TPM of the TCP in the DDN plays orderly release. This means that the connection is released upon the agreement between two TPM users at both side, while the TPM in the ISO network releases the connection upon the user request from one-side only. As discussed earlier, there could be several strategies to resolve the difference. If the DDN applications are supposed to run in both ISO and DDN, the TP-4 in the ISO network should include the orderly release function in the sublayer. If the ISO applications are supposed to run in two networks, the orderly release in the TCP can be simplified because the ISO Session Layer includes the orderly release function. The second case is considered in the design here. As shown in Figure 20.7 and 20.8, the simplification is done inside the Transport gateway to resolve the difference, while the message exchanging and the peer entity interaction between two end nodes are still kept confirmed with original protocols.

The state transition for the Connection Establish and the Connection Release inside the Transport Gateway are shown in Figure 20.9 and 20.10.

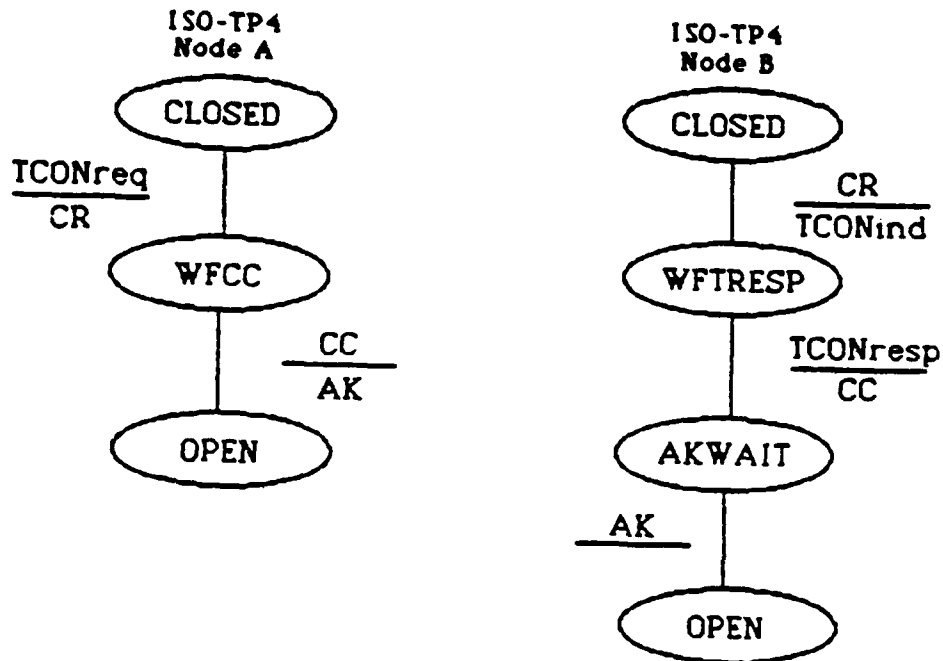


Figure 20.1 State Transition: ISO-TP4 Connection Establishment

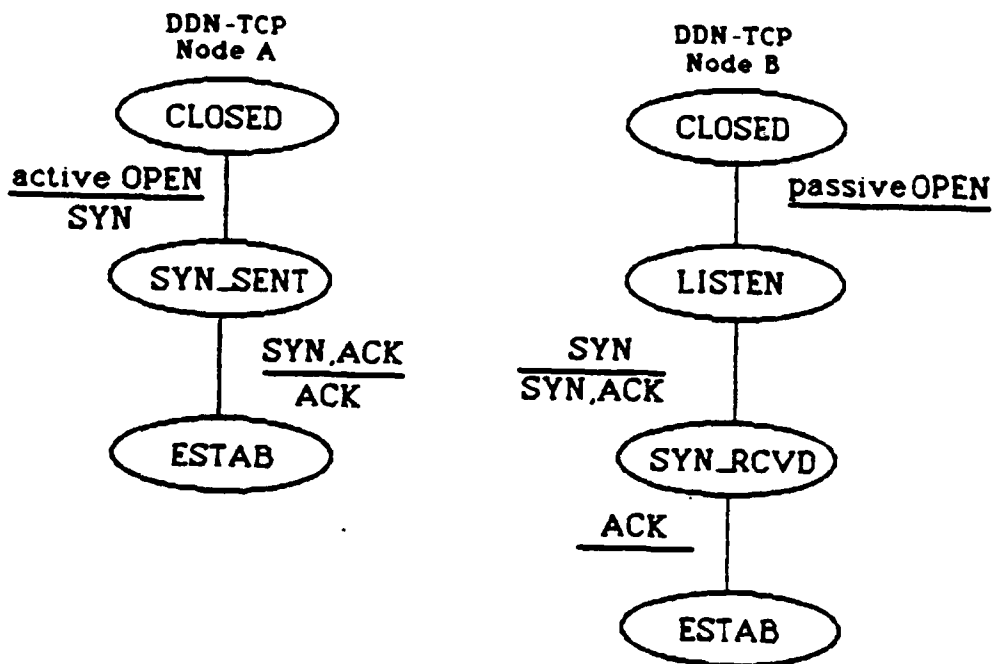


Figure 20.2 State Transition: DDN-TCP Connection Establishment

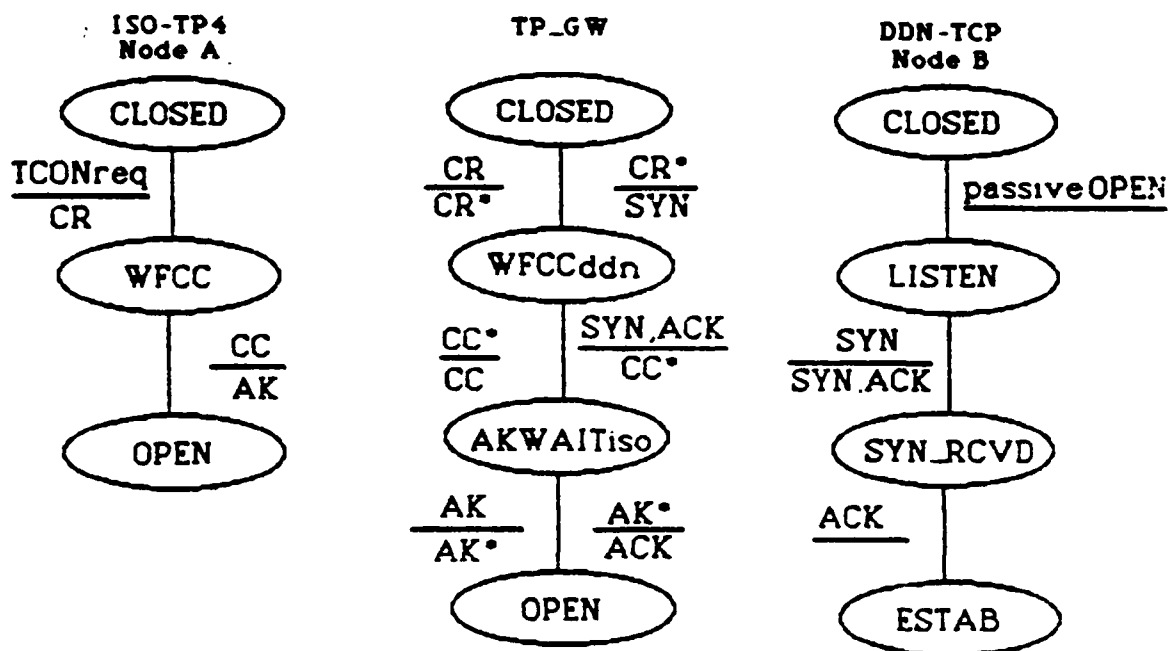


Figure 20.3 TP-Gateway Connection Establishment Initiated by ISO-TP4

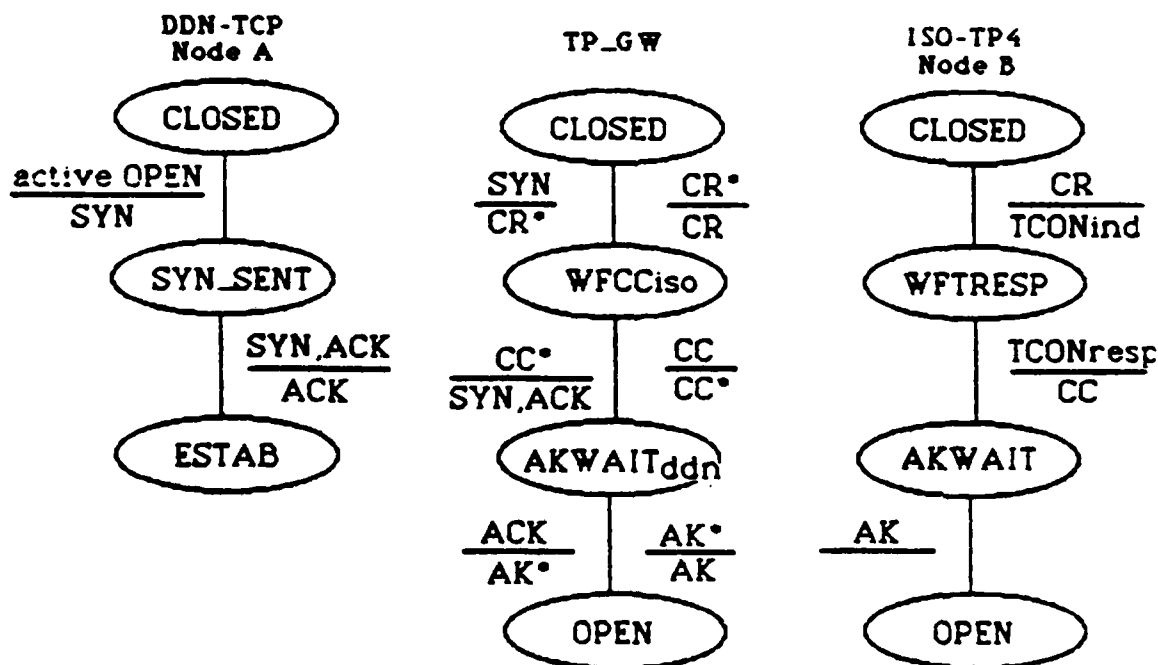


Figure 20.4 TP-Gateway Connection Establishment Initiated by DDN-TCP

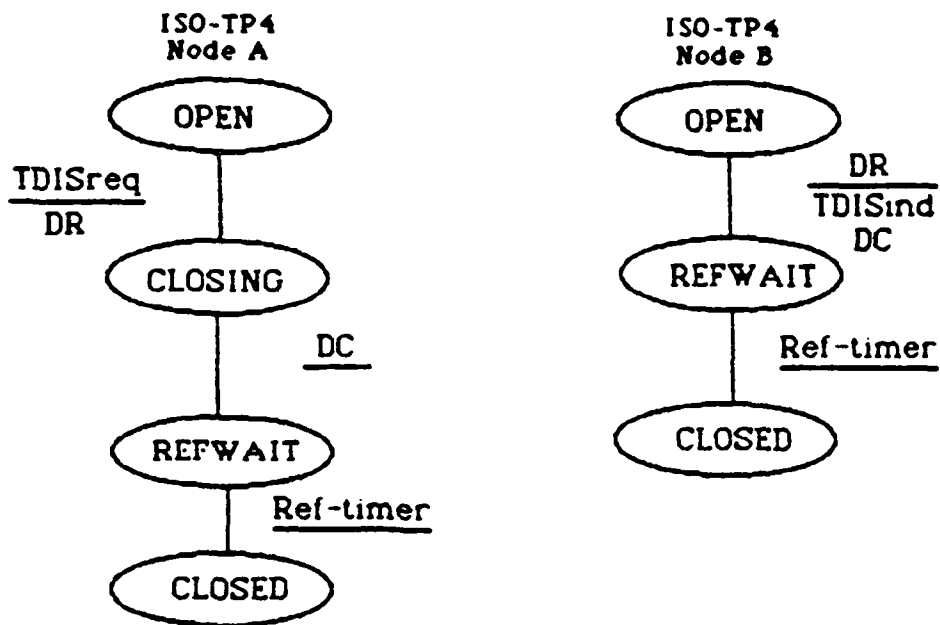


Figure 20.5 State Transition: ISO-TP4 Connection Release

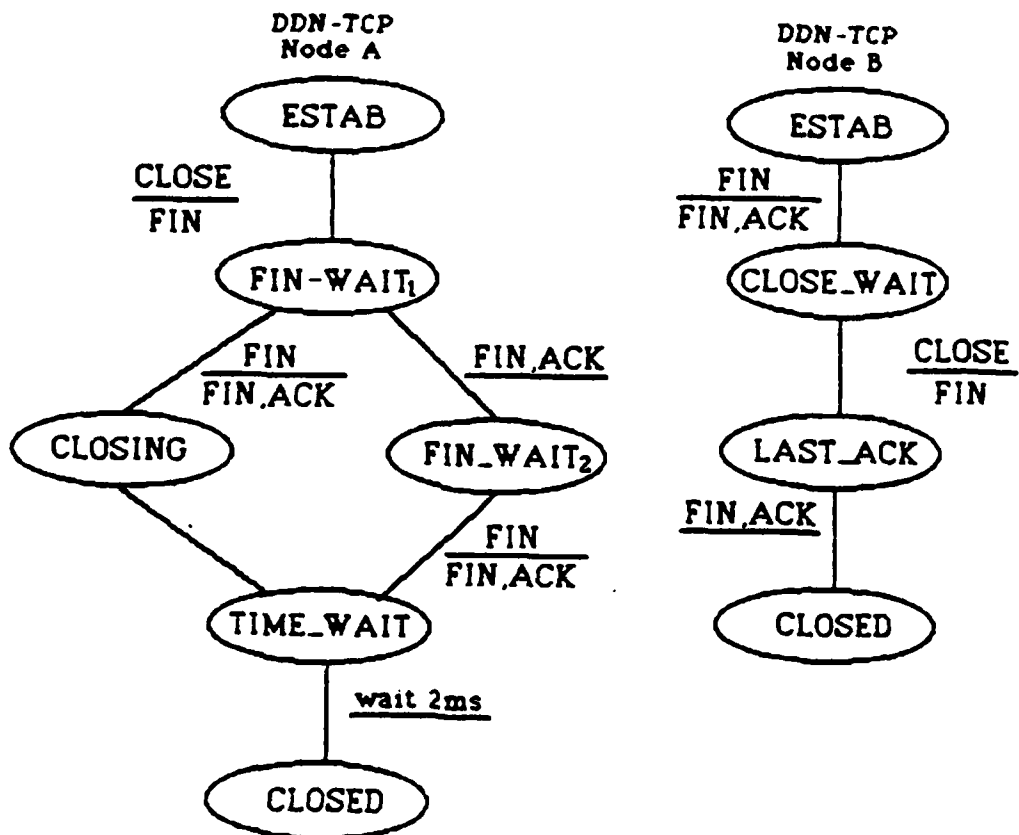


Figure 20.6 State Transition: DDN-TCP Connection Release

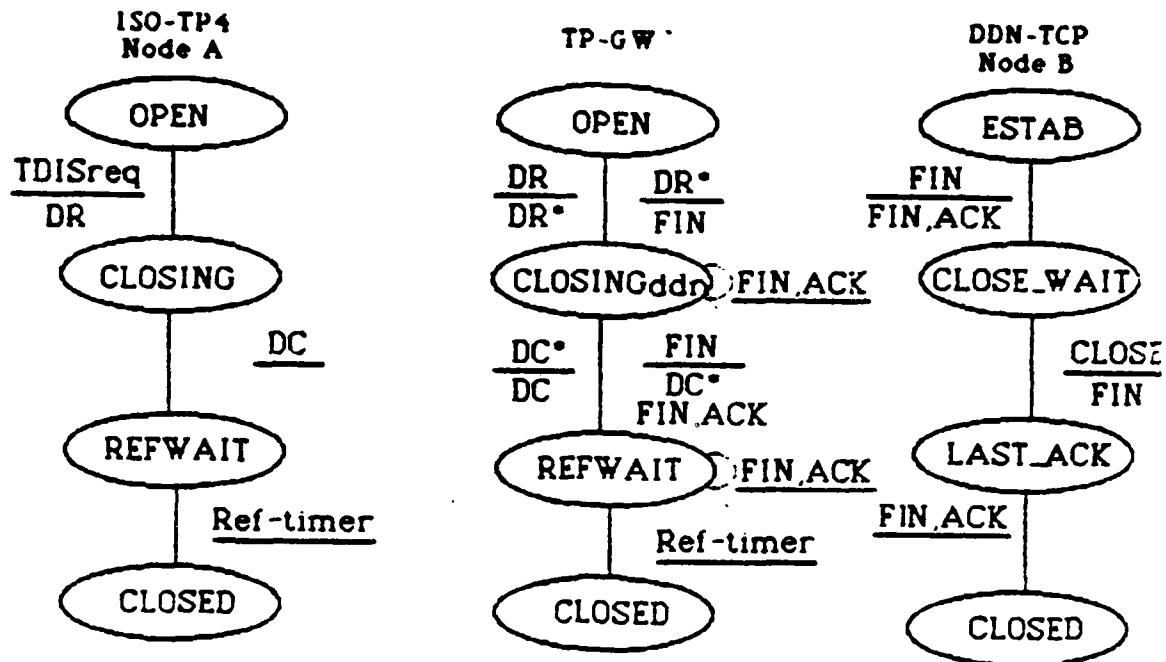


Figure 20.7 TP-Gateway Connection Release Initiated by ISO-TP4

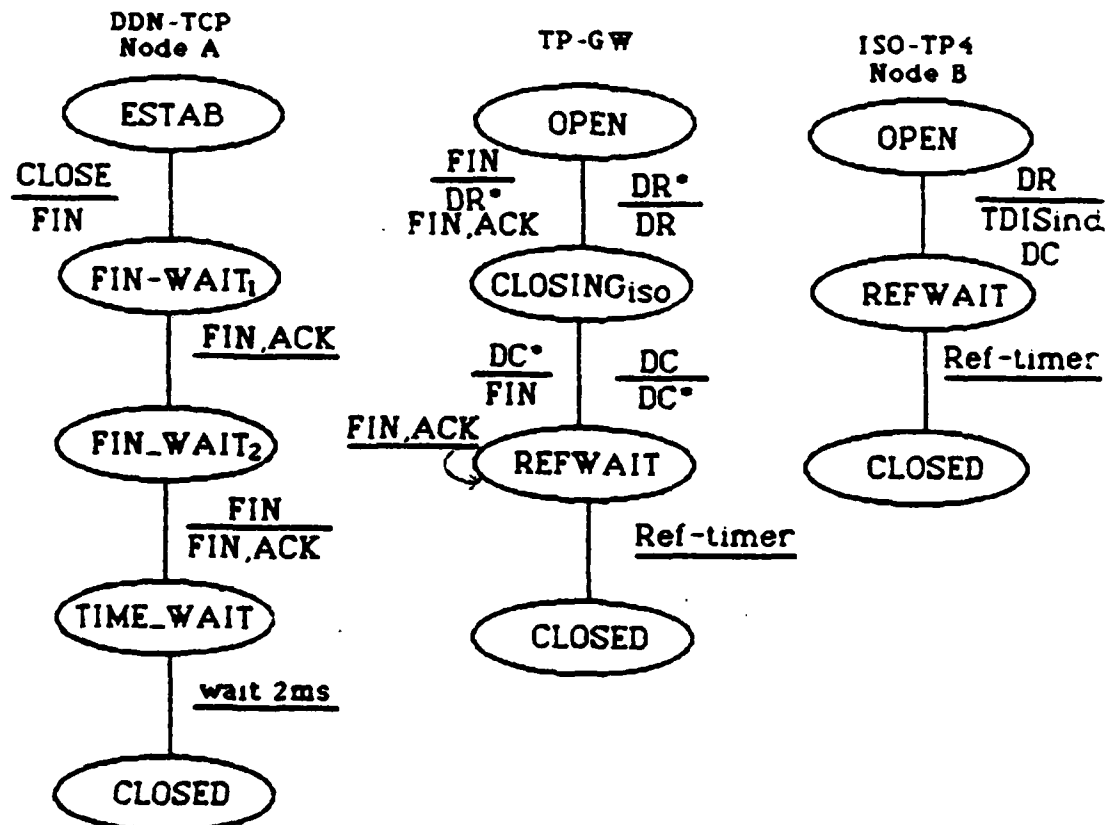


Figure 20.8 TP-Gateway Connection Release Initiated by DDN-TCP

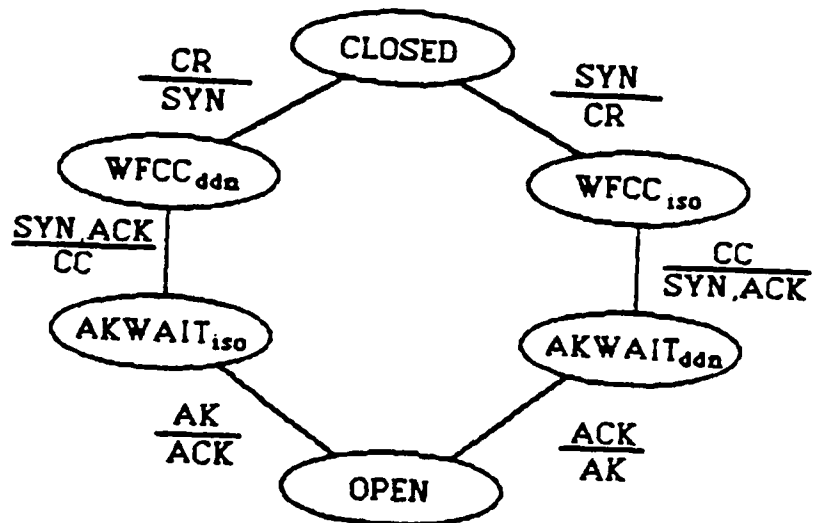


Figure 20.9 State Transition: TP-Gateway Connection Establishment

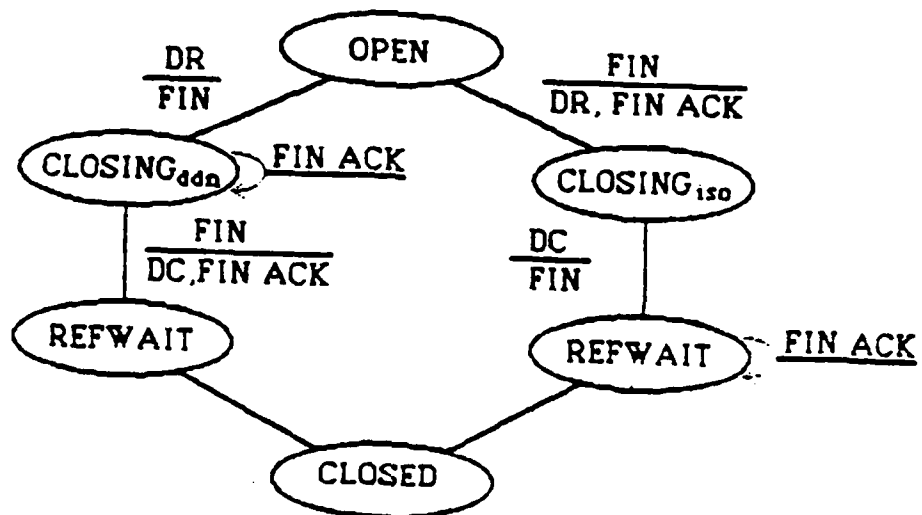


Figure 20.10 State Transition: TP-Gateway Connection Release

20.2 TRANSPORT_LAYER MODULE SPECIFICATION

Functionally speaking, this module can be further divided into two sub-modules: the TP4-dependent submodule, and the TP4-interface submodule. But due to the restrictions of the ESTELLE-like specification language, and the special situation inside the module, the relationship between the TP4-dependent and the TP4-interface submodules are specified as a parent-process and the child-processes. The TP-machines are dynamically created and terminated as the transport connection established and released. The parent process in ESTELLE can create the instance of the child process, the instances of the TP4-interface submodule are created by the TP4-dependent module upon receiving the Connection Request (CR) from ISO-IP module or from the other side of the gateway.

The commented specification for the TRANSPORT_LAYER module inside the transport gateway is enclosed in Appendix A.3.

21. CONCLUSION

Starting from the in depth discussion of internetworking requirements, this project studies the protocol interoperability issues in the DDN internet environment in detail, with emphasis on the interoperability with ISO standard protocols. Both the DDN and the ISO protocol suites are studied in terms of the basic functionalities of the layered services, service access point interfaces, and protocol peer entity mechanisms. The protocol conversions between the DDN TCP/IP and the ISO IP/TP4 is designed using ESTELLE, with the concerns of the methodology in dealing with the interoperability problem.

With such a larger volume of research efforts involved in the transport gateway design than the conventional Network Layer gateway design, it raises some very interesting questions for future studies.

- 1) Selection of better tools. LOTUS is very good in formal specification of protocols, and ESTELLE is a more implementation-oriented design tool. Still, some better tools are needed to overcome their shortcomings.
- 2) Verification of such large implementation-oriented system. With such a large system, it is very difficult to verify the design by simulation or testing. It is also painful to

APPENDIX A. TRANSPORT GATEWAY SPECIFICATION

APPENDIX A.1 GLOBAL DEFINITIONS AND THE ROOT MODULE

specification TRANSPORT_GATEWAY;

constant

```
IP_LINKER = 0;          (* IP Common Linker Module Id *)
ISO_IP_MODULE = 1;      (* ISO-IP Module Id *)
DoD_IP_MODULE = 2;      (* DoD-IP Module Id *)
TP_LINKER = 8;          (* TP Common Linker Module Id *)
ISO_TP4_MODULE = 9;     (* ISO-TP4 Module Id *)
DoD_TCP_MODULE = 10;    (* DoD-TCP Module Id *)

MAX_QUEUE = ...;        (* queue length limit *)
```

type

```
octet = 0..255;         (* one byte *)
short_word = ...;       (* two bytes *)
word_type = ...;        (* four bytes *)
data_type = ...;        (* uninterpreted string of bytes with
                           variable length, has semantics of
                           string pointer *)

SNI_addr_type = ...;    (* ISO SubNetwork Address *)
SNI_QoS_type = ...;     (* ISO SubNetwork QoS *)

SND_addr_type = ...;    (* DDN SubNetwork Address *)
SND_QoS_type = ...;     (* DDN SubNetwork QoS *)

direction_type = (in,out);      (* data flow direction *)

initiator_type = (local, remote);

queue_type = record
    buf : array [1..MAX_QUEUE] of data_type;
    last: integer;
end;
```

```

(***                                     ***)
(***   Data Structure Definitions for ISO-IP PDU   ***)
(***                                     ***)

```

```

I_IP_addr_type = record                (* ISO-IP address format *)
    length : 1..255;                   (* length, positive *)
    addr : data_type;                 (* variable length *)
end;

```

```

I_IP_option_type = record              (* ISO-IP option format *)
    code : octet;                     (* parameter code *)
    length : 1..255;                  (* length, positive *)
    value : data_type;                (* data, variable length *)
end;

```

```

I_IP_PDU_type = record                 (* ISO-IP PDU format *)
    net_protocol_id : octet;          (* network_layer_protocol_id *)
    length : octet;                   (* header length indicator *)
    version: octet;                   (* IS8473 version, 0000 0001 *)
    lifetime: octet;                  (* PDU lifetime, half-sec *)
    flags: octet;                     (* segment & error flags *)
    seg_length: short_word;           (* PDU length *)
    checksum: short_word;             (* PDU header checksum *)
    destin_addr: I_IP_addr_type;
    source_addr: I_IP_addr_type;
    (* optional *)
    data_unit_id: short_word;         (* initial PDU id *)
    seg_offset: short_word;           (* data in initial PDU data *)
    total_length: short_word;         (* length of initial PDU *)
    (* end of optional part *)
    option: I_IP_option_type;
    data: data_type;
end;

```

(* The PDU structures: I_IP_PDU_type here and D_IP_PDU_type below, are defined because the message exchanging between the ISO-IP module, the DDN IP module and the external world are at the system level. The values of the data fields are defined inside the ISO-IP and the DDN IP modules respectively. *)

```

(***                                     ***)
(***                                     ***)
(***      Data Structure Definitions for DDN-IP PDU      ***)
(***                                     ***)

```

```

D_IP_PDU_type = record
    I_length : octet;          (* IP version(4) & header length *)
    service : octet;           (* type of service *)
    tot_length: short_word;    (* PDU total length *)
    id: short_word;            (* PDU identification *)
    flags: octet;              (* segmentation flags *)
    offset: short_word;        (* fragment offset *)
    lifetime: octet;           (* PDU time to live, in sec *)
    protocol : octet;          (* next level protocol *)
    checksum: short_word;      (* header checksum *)
    source_addr: word_type;
    destin_addr: word_type;
    option: data_type;
    data: data_type;
end;

```

```

(***                                     ***)
(***      Data Structure Definitions for IP-TP      ***)
(***      Message Exchanging      ***)
(***                                     ***)

```

```

IP_TP_message_type = record
    module : octet;            (* Module Id, left 4 bits
                                for desti. module *)
    message : octet;           (* Message Id *)
    s_IP_addr : word_type;     (* source IP address *)
    d_IP_addr : word_type;     (* destin IP address *)
    data : data_type;          (* TPDU *)
end;

```

(* The message format defined above are used for the communications between the Network Layer and the Transport Layer, that is, between the ISO-IP and ISO-TP submodules, and between the DoD-IP and TCP submodules. The IP_addr fields is always required to distinguish the particular connection over one pair of sockets which is made of the IP address and the Transport TSAP address. The interpretation of the data part, that is, the TPDU, is done inside the ISO-TP and DoD-TCP submodules *)

```

(***                                     ***)
(***          Module Interaction Points          ***)
(***                                     ***)

(* ISO Network Interaction Point (to the sub-network) *)

channel I_IP_subnet_primitives (user, provider);

by user:
  I_IP_PDUreq
    (SNI_d_addr: SNI_addr_type;
     SNI_s_addr: SNI_addr_type;
     SNI_QoS: SNI_QoS_type;
     packet : I_IP_PDU_type);

by provider:
  I_IP_PDUind
    (SNI_d_addr: SNI_addr_type;
     SNI_s_addr: SNI_addr_type;
     SNI_QoS: SNI_QoS_type;
     packet : I_IP_PDU_type);

(* DDN Network Interaction Point (to the sub-network) *)

channel D_IP_subnet_primitives (user, provider);

by user:
  D_IP_PDUreq
    (SND_d_addr: SND_addr_type;
     SND_s_addr: SND_addr_type;
     SND_QoS: SND_QoS_type;
     packet : D_IP_PDU_type);

by provider:
  D_IP_PDUind
    (SND_d_addr: SND_addr_type;
     SND_s_addr: SND_addr_type;
     SND_QoS: SND_QoS_type;
     packet : D_IP_PDU_type);

```

```

(* Network Service Interaction Point (to Transport Layer) *)

channel NCEP_primitives (user, provider);

  by user:
    IP_TP_MESreq (message : IP_TP_message_type);

  by provider:
    IP_TP_MESind (message : IP_TP_message_type);


(***                                     ***)
(***                                     ***)
(***          Module Definitions          ***)
(***                                     ***)

module NETWORK_LAYER_entity_type process
  (SNSi: I_IP_subnet_primitives (user);
   (SNSd: D_IP_subnet_primitives (user);
   NSi: NCEP_primitives (provider);
   NSd: NCEP_primitives (provider);
  );

module TRANSPORT_LAYER_entity_type process
  (NSi: NCEP_primitives (user);
   NSd: NCEP_primitives (user);
  );

body NETWORK_LAYER_entity_body for NETWORK_LAYER_entity_type;
                                     external;

body TRANSPORT_LAYER_entity_body for TRANSPORT_LAYER_entity_type;
                                     external;

```

```

(***                                     ***)
(***          Common Procedures          ***)
(***                                     ***)

```

```

function d_length (mes: data_type) : integer; primitive;
    (* calculate the length of the string *)

```

```

procedure d_append (var mes: data_type;
                    mes2: data_type); primitive;
    (* append string mes2 to mes *)

```

```

function d_create (l: integer) : data_type; primitive;
    (* allocate data string space, initialize to zeros *)

```

```

function d_get (pdu: data_type; offset: integer) : octet;
    (* get one byte from the string *)
    begin
    d_get := pdu[offset];
    end;

```

```

function d_gets (pdu: data_type;
                 offset, l: integer) : data_type;
    (* get a sub-string of length l from a string at offset *)
    var
        mes: data_type;
        i: integer;
    begin
        mes := d_create(l);
        for i := 1 to l do
            mes[i] := d_get(pdu, offset+i-1);
        d_gets := mes;
    end;

```

```
function get_sword (mes: data_type; l:integer) : short_word;
```

```
    (* get a short_word of length l from the string *)
```

```
    var
```

```
        sw: short_word;
```

```
        i: integer;
```

```
    begin
```

```
        sw := 0;
```

```
        for i := 1 to l do
```

```
            sw := sw*256 + mes[i];
```

```
        get_sword := sw;
```

```
    end;
```

```
function get_word (mes: data_type; l:integer) : word_type;
```

```
    (* get a word of length l from the string *)
```

```
    var
```

```
        w: word_type;
```

```
        i: integer;
```

```
    begin
```

```
        w := 0;
```

```
        for i := 1 to l do
```

```
            w := w*256 + mes[i];
```

```
        get_word := w;
```

```
    end;
```

```
procedure d_put (var pdu: data_type;
```

```
                offset: integer; byte: octet);
```

```
    (* put one byte into the string *)
```

```
    begin
```

```
        pdu[offset] := byte;
```

```
    end;
```

```

procedure d_puts (var pdu: data_type;
                  offset: integer; segment: data_type);

    (* put s sub-string into string at offset *)

var
    l,i: integer;

begin
    l := d_length(segment);
    for i := 1 to l do
        pdu[offset+i-1] := segment[i];
    end;

procedure d_bitset (var byte: octet;
                   bit: integer;
                   flag: boolean) : octet;

    (* set the bit, as arranged to 8..1 *)

var
    b: octet;

begin
    b := 1;
    for bit := bit-1 to 1 do
        b := b*2;                                (* shift left *)
    if (flag) then
        byte := byte or b;                        (* set *)
    else
        byte := byte and (not b);                 (* reset *)
    end;
end;

```



```

function d_encode (n: integer) : octet;

    (* convert integer to octet (data_type) *)

var
    byte: octet;
    i: integer;

begin
    byte := 0;
    for i := 1 to 8 do
        begin
            if (n mod 2 <> 0) then
                d_bitset (byte,i,true);
            n := n div 2;
        end;
    d_encode := byte;
end;

```

```

function d_encode2 (n: integer) : data_type;

    (* encode integer to 2-byte string *)

var
    mes: data_type;

begin
    mes := d_create(2);
    d_put(mes,1, n div 256);
    d_put(mes,2, n mod 256);
    d_encode2 := mes;
end;

```

```

function d_encode4 (n: integer); data_type;

    (* encode integer to 4-byte string *)

var
    mes: data_type;

begin
    mes := d_create(4);
    d_puts(mes,1, d_encode2(n div 65536));
    d_puts(mes,3, d_encode2(n mod 65536));
    d_encode4 := mes;
end;

```

```

procedure clqueue (var Q: queue_type);
    (* clear queue Q *)
begin
    Q.last := 0;
end;

procedure enqueue (var Q: queue_type;
                   elem: data_type);
    (* put elem in queue Q at the tail *)
begin
    if (Q.last < MAX_QUEUE) then
        with Q do
            begin
                last := last+1;
                Q[last] := elem;
            end;
        end;
    end;
end;

```

```

function dequeue (var Q: queue_type) : data_type;
    (* get head of FIFO queue *)
var i: integer;
begin
    if (Q.last > 0) then
        with Q do
            begin
                dequeue := buf[1];
                for i := 1 to last-1 do
                    buf[i] := buf[i+1];
                last := last-1;
            end;
        else
            dequeue := d_null;
        end;
    end;
end;

```

```

function exqueue (var Q: queue_type;
                  i: integer) : data_type;

```

```

    (* get ith element of queue *)

```

```

    var j: integer;

```

```

    begin

```

```

        if (Q.last >= i) then

```

```

            with Q do

```

```

                begin

```

```

                    exqueue := buf[i];

```

```

                    for j := i to last-1 do

```

```

                        buf[j] := buf[j+1];

```

```

                    last := last-1;

```

```

                end;

```

```

            else

```

```

                exqueue := d_null;

```

```

        end;

```

```

procedure requeue (var Q: queue_type;
                   i: integer);

```

```

    (* renew the elem in queue Q by putting it at the tail *)

```

```

    var j: integer;

```

```

        elem: data_type;

```

```

    begin

```

```

        if (Q.last >= i) then

```

```

            with Q do

```

```

                begin

```

```

                    elem := Q[i];

```

```

                    for j := i to last-1 do

```

```

                        buf[j] := buf[j+1];

```

```

                    Q[last] := elem;

```

```

                end;

```

```

        end;

```

```
function chk_checksum (pdu: data_type;
                      leng: integer) : boolean;
```

```
    (* check the PDU_header checksum *)
```

```
var
```

```
    C0,C1,i : integer;
```

```
begin
```

```
    C0 := 0;
```

```
    C1 := 0;
```

```
    for i := 1 to leng do
```

```
        begin
```

```
            C0 := (C0 + d_get(pdu,i)) mod MODULUS;
```

```
            C1 := (C1 + C0) mod MODULUS;
```

```
        end;
```

```
    if ((C0=0) and (C1=0)) then
```

```
        checksum := true
```

```
    else
```

```
        checksum := false;
```

```
end;
```

```
procedure set_checksum (var pdu: data_type;
                       length, CS: integer);
```

```
    (* calculate the PDU checksum,
       length is the length of pdu header,
       CS is the position of CheckSum *)
```

```
var
```

```
    X,Y : octet;
```

```
    C0,C1,i : integer;
```

```
begin
```

```
    C0 := 0;
```

```
    C1 := 0;
```

```
    for i := 1 to length do
```

```
        begin
```

```
            C0 := (C0 + d_get(pdu,i)) mod MODULUS;
```

```
            C1 := (C1 + C0) mod MODULUS;
```

```
        end;
```

```
    length := length - CS;
```

```
    X := (-C1 + length*C0) mod MODULUS;
```

```
    Y := (C1-(length+1)*C0) mod MODULUS;
```

```
    d_put(pdu, CS, X);
```

```
    d_put(pdu, CS+1, Y);
```

```
end;
```

```

(***                                     ***)
(***             initialization          ***)
(***                                     ***)

```

initialize

```

init NETWORK_LAYER with NETWORK_LAYER_entity_body();
connect SNSi to NETWORK_LAYER.SNSi (user);
connect SNSd to NETWORK_LAYER.SNSd (user);
connect NSi to NETWORK_LAYER.NSi (provider);
connect NSd to NETWORK_LAYER.NSd (provider);

```

```

init TRANSPORT_LAYER with TRANSPORT_LAYER_entity_body();
connect NSi to TRANSPORT_LAYER.NSi (user);
connect NSd to TRANSPORT_LAYER.NSd (user);

```

end;

(* The end of the specification. It is a container with common data types, common procedures and functions, module declarations, and the initialization. The rest modules are defined externally. *)

APPENDIX A.2 NETWORK_LAYER MODULE SPECIFICATION

```
(***)
(***) NETWORK_LAYER Module Specification (***)
(***) (***)
```

```
body NETWORK_LAYER_entity_body for NETWORK_LAYER_entity_type;
```

```
constant
```

```
SOURCE_ROUTING = 1100 1000; (* opt. code for source routing *)
RECORD_ROUTING = 1100 1011; (* record route *)
ERROR_REASON = 1100 0001; (* error reason *)
SECURITY = 1100 0101; (* security *)
QOS = 1100 0011; (* QoS *)
PRIORITY = 1100 1101; (* Priority *)
PADDING = 1100 1100; (* padding *)

GW_TRANS_DELAY = ...; (* estimated GW transit delay *)
```

```
type
```

```
(* Types of Reasons for Error_report PDUs *)
```

```
error_type = (NO_ERROR,
              NOT_SPECIFIED,
              PROTOCOL_ERROR,
              INCORRECT_CHECKSUM,
              CONGESTION,
              HEADER_SYNTAX_ERROR,
              DATA_TOO_LONG,
              D_ADDR_UNREACHABLE,
              D_ADDR_UNKNOWN,
              S_ROUTING_UNSPECIFIED,
              S_ROUTING_SYNTAX_ERROR,
              S_ROUTING_UNKNOWN_ADDR,
              PATH_NOT_ACCEPTABLE,
              LIFETIME_EXPIRED_IN_TRANSIT,
              LIFETIME_EXPIRED_IN_REASSEMBLY);
```

```
(* Address_field format, as the components of route option *)
```

```
addr_field_type = record
    length: octet; (* length of addr field *)
    addr: data_type; (* addr field *)
end;
```

(* Routing Option format *)

routing_option_type = record

```
code: octet;      (* source/record routing *)
length: octet;    (* length of the option *)
flag: octet;      (* s_routing: 1=complete;
                  0=partial;
                  r_route: 0=in progress;
                  1111 1111=terminated *)
ptr: octet;       (* ptr to addr fields, from 3 *)
fields: addr_field_type;
end;
```

```
(*** Data Structure Definitions for the Message ***
*** Exchanging between IP Dependent Submodules ***
*** and Common Linker Module ***)
```

```
IP_message_type = record      (* IP message format *)
  module      : octet;        (* Module Id *)
  message     : octet;        (* message Id *)
  source_addr: word_type;     (* limited to 4 bytes *)
  destin_addr: word_type;     (* limited to 4 bytes *)
  lifetime    : octet;        (* PDU lifetime, half-sec *)
  option      : I_IP_option_type;
  in_time     : octet;        (* time arriving in GW *)
end;
```

(* The message format defined above is used to carry information between the IP modules with "the common linker module". It is necessary to overcome the problem that the TPDU data does not always carry the network addresses and some other network control information such as lifetime of PDU which are necessary for network layer control. The information will be picked up at the other side of gateway to assemble the network PDU header before sending the PDU to the remote network. *)

```
(*** Data Structure Definitions ***
*** for Storing Control Information of ***
*** a IP_message ***)
```

IP_message_handler_type = record

```
message      : octet;        (* message Id *)
lifetime     : octet;        (* PDU lifetime, half-sec *)
option       : I_IP_option_type;
in_time      : octet;        (* keep transit time *)
end;
```

```

(***)          Data Structure Definitions          (***)
(***)          for Storing Control Information of  (***)
(***)          a Pair IP Nodes                    (***)

```

```

IP_segment_type = record      (* segment & time_marker *)
    pdu: data_type;          (* PDU segment *)
    time: octet;             (* time marker *)
end;

```

```

IP_pair_type = record
    module: octet;            (* module id *)
    s_IP_addr: word_type;     (* source IP address *)
    d_IP_addr: word_type;     (* destin IP address *)
    s_routing: routing_option_type;
                                (* source routing to destin *)
    r_routing: routing_option_type;
                                (* record routing to source *)
    unitid: short_word;       (* unit_id for sending *)
    mes_id: octet;            (* mes_id for sending *)
    rcv_mes_que: queue_type of IP_message_handler_type;
                                (* receive message id queue *)
    send_mes_que: queue_type of IP_message_handler_type;
                                (* send message id queue *)
    segment_que: queue_type of IP_segment_type;
                                (* segmentation queue *)
    timestamp: word_type;     (* timestamp of action *)
end;

```

```

(***)          (***)
(***)          Module Interaction Points          (***)
(***)          (***)

```

```

(* IP Network Gateway Interaction Point (to linker module) *)
channel IP_linker_primitives (user, provider);

by user:
    IP_MESreq (message : IP_message_message_type);

by provider:
    IP_MESind (message : IP_message_message_type);

```



```

(***                                     ***)
(***                               Submodule Definitions                       ***)
(***                                     ***)

```

```

module ISO_IP_entity_type process
  (NET_INi: I_IP_subnet_primitives (user);
   NET_GWi: IP_linker_primitives (provider);
   NET_OUTi: NCEP_primitives (provider);
  );
export
  i_module_id: integer;      (* ISO IP module id *)
  isn_rcved: integer;        (* packets received from ISO SN *)
  isn_sent: integer;         (* packets sent to ISO SN *)
  int_sent: integer;         (* packets sent to ISO TP *)
  int_rcved: integer;        (* packets received from ISO TP *)
  isn_error: integer;        (* errors in packets with ISO SN *)
  int_error: integer;        (* errors in packets with ISO TP *)
end;

```

```

module DDN_IP_entity_type process
  (NET_INd: D_IP_subnet_primitives (user);
   NET_GWd: IP_linker_primitives (provider);
   NET_OUTd: NCEP_primitives (provider);
  );
export
  d_module_id: integer;      (* DDN IP module id *)
  dsn_rcved: integer;        (* packets received from DDN SN *)
  dsn_sent: integer;         (* packets sent to DDN SN *)
  dnt_sent: integer;         (* packets sent to DDN TCP *)
  dnt_rcved: integer;        (* packets received from DDN TCP *)
  dsn_error: integer;        (* errors in packets with DDN SN *)
  dnt_error: integer;        (* errors in packets with DDN TCP *)
end;

```

```

body ISO_IP_entity_body for ISO_IP_entity_type; external;

```

```

body DDN_IP_entity_body for DDN_IP_entity_type; external;

```

```

-      (***)
-      (***)      initialization      (***)
-      (***)      (***)
-
initialize
-
-      init ISO_IP with ISO_IP_entity_body();
-      connect SNSi to ISO_IP.NET_INi;      (* with ISO SubNet *)
-      connect NSi to ISO_IP.NET_OUTi;      (* with ISO TP-4 *)
-      connect NET_GWi to ISO_IP.NET_GW;
-      ISO_IP.i_module_id := 1;
-      ISO_IP.isn_rcved := 0;
-      ISO_IP.isn_sent := 0;
-      ISO_IP.int_sent := 0;
-      ISO_IP.int_rcved := 0;
-      ISO_IP.isn_error := 0;
-      ISO_IP.int_error := 0;
-
-      init DDN_IP with DDN_IP_entity_body();
-      connect SNSd to DDN_IP.NET_INd;      (* with DDN SubNet *)
-      connect NSd to DDN_IP.NET_OUTd;      (* with DDN TCP *)
-      connect NET_GWd to DDN_IP.NET_GW;
-      DDN_IP.d_module_id := 2;
-      DDN_IP.dsn_rcved := 0;
-      DDN_IP.dsn_sent := 0;
-      DDN_IP.dnt_sent := 0;
-      DDN_IP.dnt_rcved := 0;
-      DDN_IP.dsn_error := 0;
-      DDN_IP.dnt_error := 0;
-      end;
-
-
-      (***)
-      (***)      State Transition      (***)
-      (***)      (***)
-
trans
-      when NET_GWi.IP_MESind      (* from ISO_IP to Common Linker *)
-      begin
-      output NET_GWd.IP_MESreq(packet);  (* send to DDN_IP *)
-      end;
-
trans
-      when NET_GWd.IP_MESind      (* from DDN_IP to Common Linker *)
-      begin
-      output NET_GWi.IP_MESreq(packet);  (* send to ISO_IP *)
-      end;
-
end;      (* The End of NETWORK_LAYER module (Common Linker) *)

```

APPENDIX A.2.1 ISO_IP SUBMODULE

```
(***                                     ***)
(***)      ISO_IP Submodule Specification      (***)
(***)                                     (***)
```

body ISO_IP_entity_body for ISO_IP_entity_type;

constant

```
I_IP_MAX_SEGMENT_LENGTH = ...;
I_NET_DELAY = ...;          (* ISO Subnet transmit delay *)
I_REASSEMBLY_DELAY = ...;   (* Reassembly delay up_limit *)
I_LIFETIME := ...;          (* Lifetime for PDUs *)
I_IP_ADDRESS := ...;        (* local IP address *)

I_SN_LOCAL_ADDR := ...;     (* local SubNet address *)
I_SN_QOS := ...;            (* local SubNet QoS *)

I_NET_PROTOCOL_ID = 129;    (* 1000 0001 in binary *)
I_IP_VERSION = 1;          (* 0000 0001 *)

SEGMENT_PERMIT = 128;       (* 1000 0000 *)
MORE_SEGMENT = 64;         (* 0100 0000 *)
ERROR_REPORT = 32;         (* 0010 0000 *)

DATA_PDU = 28;              (* 0001 1100 *)
ERROR_PDU = 1;              (* 0000 0001 *)

FLAG_type = (OK, EXPIRED, INCOMPLETE);
```

var

```
I_IP_pair: queue_type of IP_pair_type;
mod_id: octet;
mes_id: integer;
cur_I_IP_pdu,err_pdu: I_IP_PDU_type;
cur_IP_TP_mes: IP_TP_message_type;
cur_IP_mes: IP_message_type;
cur_IP_handler: IP_message_handler_type;
opt_ptr: I_IP_option_type;
s_ip_addr,d_ip_addr: word_type;
s_route,r_route: routing_option_type;
I_SN_addr: SNI_addr_type;

pair_index: integer;
err_flag: error_type;
transit_time: octet;
pdu_error: integer;
```

```

(***                                     ***)
(***           Common Procedures         ***)
(***                                     ***)

```

```
function get_data_unit_id : short_word;
```

```
    (* get unique Data_Unit_Id *)
```

```

begin
with I_IP_pair[pair.index] do
begin
unitid := unitid+1;
get_data_unit_id := unitid;
end;
end;

```

```
function get_option_length(pdu: I_IP_PDU_type) : integer;
```

```
    (* get the length of options *)
```

```

begin
get_option_length := pdu.length - pdu.destin_addr.length
                    - 11 - pdu.source_addr.length;
if (pdu.flags and SEGMENT_PERMIT) then
get_option_length := get_option_length - 6;
end;

```

```
function conv_routing(opt_ptr: I_IP_option_type) :
                                routing_option_type;
```

```
    (* convert the routing direction *)
```

```
var
```

```

i,j,l,k,m: integer;
opl: ^routing_option_type;

```

```

begin
m := opt_ptr.value[2]-1;          (* use the ptr as length *)
opl := d_create(m+2);
opl.code := SOURCE_ROUTING;
opl.length := m;
opl.flag := 1;                   (* type 1 as complete routing *)
opl.ptr := 3;                    (* ptr to beginning *)

i := 3;                          (* copied from beginning *)
j := m-1;                        (* copied to from end:3-1 *)
while (i<m) do                   (* reverse the order *)
begin
l := opt_ptr.value[i];          (* length of field *)

```

```

-       j := j - 1 - 1;
-       opl.fields[j] := 1;
-       for k := 1 to 1 do
-           opl.fields[j+k] := opt_ptr.value[i+k];
-       end;
-       conv_routing := opl;
-       end;

```

```

- procedure one_segment(pdu: I_IP_PDU_type);

```

```

-     (* output one IP_PDU *)

```

```

-     var

```

```

-         i,j,k,leng: integer;
-         s: data_type;

```

```

-     begin

```

```

-     with pdu do

```

```

-         begin

```

```

-         net_protocol_id := I_NET_PROTOCOL_ID;

```

```

-         version := I_IP_VERSION;

```

```

-         seg_length := length + d_length(data);

```

```

-         leng := get_option_length(pdu);

```

```

-         opt_ptr := ^option;

```

```

-         s_route := d_null;      (* looking for SOURCE_ROUTING *)

```

```

-         while ((s_route=d_null) and (leng>0)) then

```

```

-             if (opt_ptr.code=SOURCE_ROUTING) then

```

```

-                 s_route:=d_gets(opt_ptr,1,opt_ptr.length+2);

```

```

-             else

```

```

-                 begin

```

```

-                     leng := leng - opt_ptr.length;

```

```

-                     opt_ptr := ^opt_ptr.value[opt_ptr.length+1];

```

```

-                 end;

```

```

-             if (s_route=d_null) then

```

```

-                 s_route :=

```

```

-                     conv_routing(I_IP_pair.buf[pair_index].r_routing);

```

```

-                 k := s_route.ptr - 2;      (* pointer to field *)

```

```

-                 j := s_route.fields[k];    (* the length *)

```

```

-                 s := d_gets(s_route.fields, k+1, j);      (* get field *)

```

```

-                 I_SN_addr := trans_SN_addr(s); (* translate to SN_addr *)

```

```

-                 opt_ptr.value[2] := opt_ptr.value[2] + j + 1;

```

```

-                                     (* modify the pointer *)

```

```

-                 checksum := 0;

```

```

-                 set_checksum (pdu, length, 7);

```

```

-                 end;

```

```

-         output NET_INi.I_IP_PDUreq (I_SN_addr,
-                                     I_SN_LOCAL_ADDR,
-                                     I_SN_QOS,
-                                     pdu);

```

```

-     end;

```

```

procedure error_pdu (err: error_type;
                    ptr, leng: integer;
                    pdu: I_IP_PDU_type);

    (* send an Error_Report pdu *)

var
    opt_ptr: I_IP_option_type;

begin
    opt_ptr := d_create(4);
    opt_ptr.code := ERROR_REASON;
    opt_ptr.length := 2;
    opt_ptr.value[1] := err;
    opt_ptr.value[2] := ptr;
    d_append(opt_ptr, I_IP_pair.buf[pair_index].r_routing);

with err_pdu do
    (* Make ERROR PDU *)
    begin
        lifetime := I_LIFETIME;
        flags := (pdu.flags and SEGMENT_PERMIT) or ERROR_PDU;
        destin_addr.length := pdu.source_addr.length;
        destin_addr.addr := pdu.source_addr.addr;
        source_addr.length := 4;
        source_addr.addr := I_IP_ADDRESS;
        option := opt_ptr;
        length := 11 + destin_addr.length + source_addr.length
                + d_length(option);
        data := d_gets(pdu, 1, leng);
        if (flags and SEGMENT_PEMIT) then
            begin
                length := length + 6;
                data_unit_id := get_data_unit_id();
                seg_offset := 0;
                total_length := length + d_length(data);
            end;
        one_segment(err_pdu);
    end;
end;

```

```

function pair_match : integer;

    (* match the I_IP_pair with s/d_ip_addr,
       set and return the index *)

var
    i, j, k, leng: integer;
    t: word_type;

begin
    j := 0;

```

```

for i := 1 to I_IP_pair.last do      (* look for the pair with
                                     same IP_address info *)
    with I_IP_pair.buf[i] do
        if ((s_IP_addr = s_ip_addr) and
            (d_IP_addr = d_ip_addr)) then
            j := i;

            if ((j <> 0) and (mod_id = 0)) then          (* matched *)
                mod_id := I_IP_pair.buf[j].module/16;
            else if ((j <> 0) and (mod_id <> 0) and      (* matched *)
                (I_IP_pair.buf[j].module/16 = 0)) then
                I_IP_pair.buf[j].module := mod_id*16 + i_module_id;
            else if (j = 0) then      (* need fill in new IP_pair entry *)
                begin
                    if (I_IP_pair.last < MAX_QUEUE) then
                        begin
                            I_IP_pair.last := I_IP_pair.last + 1;
                            j := I_IP_pair.last;
                        end;
                    else
                        (* no empty slot *)
                        begin
                            t := cur_time();
                            for i := 1 to I_IP_pair.last do
                                if (I_IP_pair.buf[i].timestamp < t) then
                                    begin
                                        j := i;
                                        t := I_IP_pair.buf[i].timestamp;
                                    end;
                                pair_index := j;
                                for k := 1 to segment_que.last do
                                    (* clean reassembly queue by Error/Report *)
                                    with segment_que.buf[k] do
                                        error_pdu(CONGESTION, 0, pdu.length, pdu);
                                        (* send Error/Report *)
                                    end;
                                end;
                                with I_IP_pair.buf[j] do (* fill in *)
                                    begin
                                        (* use empty/oldest slot *)
                                        module = mod_id * 16 + i_module_id;
                                        s_IP_addr := s_ip_addr;
                                        d_IP_addr := d_ip_addr;
                                        s_routing := d_null;
                                        d_routing := d_null;
                                        rcv_mes_que.last := 0;
                                        send_mes_que.last := 0;
                                        segment_que.last := 0;
                                        timestamp = cur_time();
                                    end; (* with: fill in *)
                                end; (* if j=0 *)
                            pair_index := j;
                            pair_match := j;
                        end;
                    end;
                end;
            end;
        end;
    end;

```

```

(***)
(***)      initialization      (***)
(***)
(***)

```

initialize

```

    pdu_error := 0;
    I_IP_pair.last := 0;
end;

```

```

(***)
(***)      State Transition    (***)
(***)
(***)

```

```

trans
  when NET_INi.I_IP_PDUind      (* from ISO subnetwork *)

```

```

    var
      i,ii,j,k,leng,total: integer;
      t: word_type;
      pdu1: I_IP_PDU_type;
      flag: FLAG_type;

```

```

begin
  transit_time := cur_time();
  cur_I_IP_pdu := packet;
  if (cur_I_IP_pdu.source_addr.length>4) then
    pdu_error := pdu_error+1;      (* PDU dropped *)
  else if (cur_I_IP_pdu.destin_addr.length>4) then
    pdu_error := pdu_error+1;      (* PDU dropped *)
  else
    begin
      s_ip_addr := cur_I_IP_pdu.source_addr.addr;
      d_ip_addr := cur_I_IP_pdu.destin_addr.addr;
      mod_id := 0;
      j := pair_match();
      err_flag := NO_ERROR;
      s_route := d_null;
      r_route := d_null;
      with cur_I_IP_pdu do
        with I_IP_pair.buf[j] do
          begin
            if(chk_checksum(cur_I_IP_pdu,length)=false) then
              err_flag := INCORRECT_CHECKSUM;
            else
              begin

```



```

lifetime := lifetime - I_LIFETIME;
leng := get_option_length(cur_I_IP_pdu);
opt_ptr := ^option;
while (leng>0) then
    if (opt_ptr.code=SOURCE_ROUTING) then
        begin
            s_route:=d_gets(opt_ptr,1,opt_ptr.length+2);
            s_routing := s_route;
        end;
    else if (opt_ptr.code=RECORD_ROUTING) then
        begin
            r_route := conv_routing(opt_ptr);
            r_routing := r_route;
        end;
    else
        begin
            leng := leng - opt_ptr.length;
            opt_ptr := ^opt_ptr.value[opt_ptr.length+1];
        end;
    end;
if((err_flag=NO_ERROR) and (lifetime<=0)) then
    err_flag := LIFETIME_EXPIRED_IN_TRANSIT;
else if((err_flag=NO_ERROR) and (s_route=d_null)) then
    err_flag := S_ROUTING_UNSPECIFIED;

if (err_flag<>NO_ERROR) then (* send Error/Report *)
    begin
        error_pdu(err_flag, 1, length, cur_I_IP_pdu);
        pdu_error := pdu_error+1; (* PDU dropped *)
    end;
else
    begin (* handle segment *)
        flag := OK;
        ii := 0;
        if (flags and SEGMENT_PERMIT=0) then
            begin
                pdul := cur_I_IP_pdu; (* no segmentation *)
                total := seg_length;
                k := total;
            end;
        else
            begin
                total := total_length;
                i := 1;
                while ((i<segment_que.last) and (data_unit_id
                    <segment_que.buf[i].pdu.data_unit_id)) do
                    i := i + 1;
                ii := i;
                k := 0;
                while ((flag=OK) and (i<segment_que.last) and
                    (k<total) and (data_unit_id
                    =segment_que.buf[i].pdu.data_unit_id)) do
                    with segment_que.buf[i] do
                        begin
                            if (seg_offset=k) then (* of cur_I_IP_pdu *)

```

```

begin
  if (k=0) then
    pdu1 := cur_I_IP_pdu;
  else
    d_append(pdu1.data, data);
    k := k+seg_length-length;
    (* Length of data *)
  end;
  if (pdu.lifetime<=cur_time()- time) then
    flag := EXPIRED;
  else if (pdu.seg_offset>k) then
    flag := INCOMPLETE;
  else
    begin
      if (k=0) then
        pdu1 := segment_que.buf[i];
      else
        d_append(pdu1.data,pdu.data;
        k := k+pdu.seg_length-pdu.length;
      end;
      if (flag=OK) then
        i := i+1;
      else
        (* stop *)
        i := segment_que.last+1;
      end; (* while *)
    end;
    i := ii;
  end; (* else SP *)
  if (((flag=OK) and (k<total)) or (* miss last seg. *)
    (flag=INCOMPLETE) then
    begin (* PDU is not complete yet, queueed *)
      for k := i to segment_que.last do
        segment_que.buf[i+1] := segment_que.buf[i];
        segment_que.buf[i].pdu := cur_I_IP_pdu;
        segment_que.buf[i].time := cur_time();
        segment_que.last := segment_que.last+1;
      end;
    else if (i>0) then (* need to extract segments
      expired/reassembled *)
      while ((i<segment_que.last) and (data_unit_id=
        segment_que.buf[i].pdu.data_unit_id)) do
        begin
          exqueue(segment_que, i);
          i := i+1;
        end;
      if (flag=EXPIRED) then
        error_pdu(LIFETIME_EXPIRED_IN_REASSEMBLY,
          1, length, cur_I_IP_pdu);
      else if (k=total) then
        begin
          with cur_IP_TP_mes do
            begin
              module := I_IP_pair.buf[j].module;
              mes_id := mes_id + 1;
              if (mes_id=0) then

```

```

        mes_id := 1;
        message := mes_id;
        s_IP_addr := s_IP_addr;
        d_IP_addr := d_IP_addr;
        data := pdu1.data;
        end;
    output NET_OUTi.I_IP_PDUind (cur_IP_TP_mes);

    with cur_IP_mes do
        begin
            (* make GW packet *)
            module := I_IP_pair.module;
            message := mes_id;
            source_addr := s_IP_addr;
            destin_addr := d_IP_addr;
            lifetime := pdu1.lifetime
                - (cur_time()-transit_time);
            option := pdu1.option;
            end;
        output NET_GWi.IP_MESind (cur_IP_mes);

        with cur_IP_handler do
            begin
                (* make IP_message_handler *)
                message := mes_id;
                lifetime := pdu.lifetime;
                option := pdu.option;
                end;
            enqueue (rcv_mes_queue, cur_IP_handler);

            end; (* if flag *)
        end; (* else err_flag *)

        timestamp := cur_time;
        end; (* with-with *)
    end; (* else *)
end;

```

```

trans
  when NET_GWi.IP_MESreq          (* from GW common linker *)

    var
      j,leng: integer;

    begin
      cur_IP_mes := packet;
      with cur_IP_mes do
        begin
          mod_id := module/16 + (module mod 16)*16;
          d_ip_addr := source_addr;
          s_ip_addr := destin_addr;
          j := pair_match();

          with I_IP_pair.buf[j] do
            begin
              s_route := s_routing;
              r_route := r_routing;
              if ((s_route=d_null) or (r_route=d_null)) then
                begin
                  opt_ptr := ^option;
                  leng := d_length(option);
                  while (leng>0) then
                    if ((r_route=d_null) and
                      (opt_ptr.code=SOURCE_ROUTING)) then
                      begin
                        r_route:= conv_routing(opt_ptr);
                        r_routing := r_route;
                        end;
                      else if ((s_route=d_null) and
                        (opt_ptr.code=RECORD_ROUTING)) then
                        begin
                          s_route := d_gets(opt_ptr,1,opt_ptr.length+2);
                          s_routing := s_route;
                          end;
                        else
                          begin
                            leng := leng - opt_ptr.length;
                            opt_ptr := ^opt_ptr.value[opt_ptr.length+1];
                            end;
                          end; (* if *)
                    with cur_IP_handler do
                      begin
                        (* make IP_message_handler *)
                        message := mes_id;
                        lifetime := pdu.lifetime;
                        option := pdu.option;
                        in_time := cur_time();
                        end;
                      enqueue (send_mes_que, cur_IP_handler);
                      timestamp := cur_time;
                    end; (* with I_IP_pair.buf[j] *)
                  end; (* with cur_IP_mes *)
                end;
            end;
          end;

```

```

trans
  when NET_OUTi.I_IP_PDureq                                (* from TP-4 *)

    var
      i,j,k,n: integer;
      handler: IP_message_handler_type;
      ip_data: data_type;

    begin
      cur_IP_TP_mes := packet;
      with cur_IP_TP_mes do
        begin
          mod_id := module/16 + (module mod 16)*16;
          mes_id := message;
          s_ip_addr := d_IP_addr;
          d_ip_addr := s_IP_addr;

          j := 0;
          for i := 1 to I_IP_pair.last do
            with I_IP_pair.buf[i] do
              if ((s_ip_addr=s_IP_addr) and
                  (d_ip_addr=d_IP_addr)) then
                j := i;
              end if;
            end with;
          end for;

          if (j=0) then
            pdu_error := pdu_error+1;
            (* It is supposed to have a match here
               because even if the IP_module at the
               gateway side initiated the session, the
               IP_message has been transferred over
               faster to establish an entry earlier. *)
          else
            with I_IP_pair.buf[j] do
              begin
                pair_index := j;                                (* global *)
                k := 0;
                if (mes_id<>0) then
                  for i := 1 to send_mes_que.last do
                    if (send_mes_que.buf[i].message=mes_id) then
                      k := i;
                    end if;
                  end for;
                if (k=0) then
                  k := 1;      (* if no match, use 1st one *)
                end if;
                handler := exqueue(send_mes_que, k);
                with cur_I_IP_pdu do
                  begin
                    destin_addr.length := 4;
                    destin_addr.addr := s_ip_addr;
                    source_addr.length := 4;
                    source_addr.addr := d_ip_addr;
                    flags := ERROR_REPORT or DATA_PDU;
                    option := handler.option;
                    lifetime := handler.lifetime
                      - (cur_time() - handler.in_time);
                    length := d_length(option) + 19;
                  end with;
                end with;
              end with;
            end with;
          end if;
        end with;
      end with;
    end when;
  end trans;

```

```

data := cur_IP_TP_mes.data;
(* segmentation & output *)
n := d_length(data);
if (n > I_IP_MAX_SEGMENT_LENGTH) then
begin
length := length+6;
flags := flags or SEGMENT_PERMIT;
data_unit_id := get_data_unit_id;
seg_offset := 0;
total_length := length + n;
ip_data := data;
i := 1;
while (n>i*I_IP_MAX_SEGMENT_LENGTH) do
begin
flags := flags or MORE_SEGMENT;
seg_offset := seg_offset +
I_IP_MAX_SEGMENT_LENGTH;
data := d_gets(ip_data,
(i-1)*I_IP_MAX_SEGMENT_LENGTH+1,
I_IP_MAX_SEGMENT_LENGTH);
one_segment(cur_I_IP_pdu);
i := i+1;
n := d_length(ip_data);
end;
flags := flags and (not MORE_SEGMENT);
data:=d_gets(ip_data,
(i-1)*I_IP_MAX_SEGMENT_LENGTH+1,
d_length(ip_data)
-I_IP_MAX_SEGMENT_LENGTH);
end; (* if n > *)

one_segment();
end; (* with cur_I_IP_pdu *)
timestamp := cur_time;
end; (* with I_IP_pair.buf[j] *)
end; (* with cur_IP_TP_mes *)
end; (* trans *)

end; (* of ISO_IP_entity_body *)

```

APPENDIX A.2.2 DDN_IP SUBMODULE

```

(***                                     ***)
(***          DDN_IP Submodule Specification          ***)
(***                                     ***)

```

body DDN_IP_entity_body for DDN_IP_entity_type;

constant

```

D_IP_MAX_SEGMENT_LENGTH = ...;
D_NET_DELAY = ...;          (* DDN Subnet transmit delay *)
D_REASSEMBLY_DELAY = ...;   (* Reassembly delay up_limit *)
D_LIFETIME := ...;          (* Lifetime for PDUs *)
D_IP_HOST_ADDRESS := ...;   (* local IP host address *)
D_IP_NET_ADDRESS := ...;    (* local IP net address *)

D_SN_LOCAL_ADDR := ...;     (* local SubNet address *)
D_SN_QOS := ...;            (* local SubNet QoS *)

HOST_A_MASK = 2**24-1;      (* mask for CLASS A host addr *)
HOST_B_MASK = 2**16-1;      (* mask for CLASS B host addr *)
HOST_C_MASK = 2**8-1;       (* mask for CLASS C host addr *)

NET_A_MASK = 2**31-1;       (* mask for CLASS A net addr *)
NET_B_MASK = 2**30-1;       (* mask for CLASS B net addr *)
NET_C_MASK = 2**29-1;       (* mask for CLASS C net addr *)

NET_A_SHIFT = 2**24;        (* r-shift for CLASS A net addr *)
NET_B_SHIFT = 2**16;        (* r-shift for CLASS B net addr *)
NET_C_SHIFT = 2**8;         (* r-shift for CLASS C net addr *)

CLASS_A_FLAG = 2**31;       (* CLASS A host addr limit *)
CLASS_B_FLAG = 2**31+2**30;  (* CLASS B host addr limit *)
CLASS_C_FLAG = 2**31+2**30+2**29; (* CLASS C host addr limit *)

D_IP_VERSION = 4;

DONT_FRAGMENT = 64;
MORE_FRAGMENT = 32;

ICMP_PROTO = 1;             (* protocol field *)

OPTION_COPIED_MASK = 128;   (* copied flag in opt_code *)
OPTION_CLASS_MASK = 96;     (* option class in opt_code *)
OPTION_NUMBER_MASK = 31;    (* option number opt_code *)

OPTION_CLASS_SHIFT = 32;

CLASS_CONTROL = 0;          (* option class *)
CLASS_MEASURE = 2;

```

```

OPT_END = 0;                                (* option number *)
NO_OP = 1;
SECURITY = 2;
L_SOURCE_ROUTING = 3;
TIMESTAMP = 4;
RECORD_ROUTING = 7;
STREAM_ID = 8;
SOURCE_ROUTING = 9;

```

```

ICMP_ECHO_REPLY = 0;                        (* ICMP type *)
ICMP_DESTIN_UNREACHABLE = 3;
ICMP_SOURCE_QUENCH = 4;
ICMP_REDIRECT = 5;
ICMP_ECHO = 8;
ICMP_TIME_EXCEEDED = 11;
ICMP_PARAM_PROBLEM = 12;
ICMP_TIMESTAMP = 13;
ICMP_TIMESTAMP_REPLY = 14;
ICMP_INFO_REQUEST = 15;
ICMP_INFO_REPLY = 16;

```

```

ICMP_NET_UNREACHABLE = 0;                   (* ICMP code *)
ICMP_HOST_UNREACHABLE = 1;
ICMP_PROTO_UNREACHABLE = 2;
ICMP_PORT_UNREACHABLE = 3;
ICMP_FRAGMENT_FAILED = 4;
ICMP_SOURCE_ROUTE_FAILED = 5;

```

```

ICMP_LIFETIME_EXCEEDED = 0;
ICMP_REASSEMBLY_EXCEEDED = 1;

```

```

FLAG_type = (OK, EXPIRED, INCOMPLETE, COMPLETE);

```

type

```

ICMP_type = record
    typ: octet;
    code: octet;
    checksum: short_word;
    data: data_type;
end;

```



```

var
  D_IP_pair: queue_type of IP_pair_type;
  mod_id: octet;
  mes_id: integer;
  cur_D_IP_pdu,err_pdu: D_IP_PDU_type;
  cur_IP_TP_mes: IP_TP_message_type;
  cur_IP_mes: IP_message_type;
  cur_IP_handler: IP_message_handler_type;
  opt_ptr: D_IP_option_type;
  s_host_addr,d_host_addr: word_type;
  s_net_addr,d_net_addr: word_type;
  s_ip_addr,d_ip_addr: word_type;
  host_mask,net_mask: word_type;
  net_shift: word_type;
  s_route,r_route: option_type;
  D_SN_addr: SNI_addr_type;
  ICMP_ptr: ^ICMP_type;

  pair_index: integer;
  err_flag,err_code: octet;
  transit_time: octet;

  pdu_error: integer;
  icmp_unreachable: integer;
  icmp_quench: integer;
  icmp_exceeded: integer;
  icmp_parameter: integer;

```

```

(***)
(***)      Common Procedures      (***)
(***)      (***)

```

```

function trans_d_ip_addr(addr: word_type) : word_type; primitive;
    (* translate DDN_IP address to GW_IP address *)

```

```

function trans_g_ip_addr(addr: word_type) : word_type; primitive;
    (* translate GW_IP address to DDN_IP address *)

```

```

function trans_d_lifetime(lifetime: octet) : octet; primitive;
    (* translate DDN_IP lifetime to GW_IP lifetime *)

```

```

function trans_g_lifetime(lifetime: octet) : octet; primitive;
    (* translate GW_IP lifetime to DDN_IP lifetime *)

```

```

function trans_d_option(var opt_length: integer;
                        option: data_type;
                        pdu: D_IP_PDÜ_type) : data_type; primitive;
    (* translate DDN_IP options to GW_IP options *)

```

```

function trans_g_option(var opt_length: integer;
                        option: data_type;
                        pdu: D_IP_PDÜ_type) : data_type; primitive;
    (* translate GW_IP options to DDN_IP options *)

```

```

(* NOTICE the differences of the options:
PRECEDENCE, DELAY, THROUGHPUT, and RELIABILITY of DDN-IP
are in the IP header, while ISO-IP keeps them in options *)

```

```

function one_option_length(code: octet) : integer; primitive;
    (* get the length of one DDN-IP option *)

```

```

function conv_routing(opt_ptr: D_IP_option_type) :
    routing_option_type; primitive;

    (* convert the routing direction
       between the SOURCE_ROUTING and RECORDED_ROUTING *)

procedure copy_options(pdu: D_IP_PDU_type); primitive;

    (* copy options according to COPIED flag in options
       for those PDUs with offset>0 *)

procedure send_ICMP (err_type, err_code: octet; pdu: D_IP_PDU_type);
    primitive;

    (* send an ICMP for echo *)

```

```

function get_data_unit_id : short_word;

    (* get unique Data_Unit_Id *)

begin
with D_IP_pair[pair.index] do
begin
unitid := unitid+1;
get_data_unit_id := unitid;
end;
end;

function get_option_length(pdu: D_IP_PDU_type) : integer;

    (* get the length of options *)

begin
get_option_length := (pdu.I_length - 5) * 4;
end;

function opt_num(code: octet) : integer;

    (* get the option number from the option code *)

begin
opt_num := code and OPTION_NUMBER_MASK;
end;

procedure one_segment(pdu: D_IP_PDU_type);

    (* output one IP_PDU *)

var
i,j,k,leng,length: integer;
s: word_type;

begin
with pdu do
begin
length := (I_length and 15) * 4;
I_length := (I_length and 15) + D_IP_VERSION*16;
tot_length := length + d_length(data);

leng := get_option_length(pdu);
opt_ptr := ^option;

```

```

s_route := d_null;    (* looking for SOURCE_ROUTING *)
while ((s_route=d_null) and (leng>0)) then
  if (opt_num(opt_ptr.code)=SOURCE_ROUTING) then
    s_route:=d_gets(opt_ptr,1,opt_ptr.length);
  else
    begin
      k := one_option_length(opt_ptr.code);
      leng := leng - k;
      opt_ptr := ^opt_ptr + k;
    end;
  if (s_route=d_null) then
    s_route :=
      conv_routing(D_IP_pair.buf[pair_index].r_routing);
  k := s_route.value[1]      (* get pointer to field *)
  s := get_word(^s_route.value[k-2], 4);
                                (* get the IP address *)
  D_SN_addr := trans_SN_addr(s); (* translate to SN_addr *)
  opt_ptr.value[1] := opt_ptr.value[1] + 4;
                                (* modify the pointer *)
  checksum := 0;
  set_checksum (pdu, length, 11);
end;

output NET_INi.D_IP_PDUREq (D_SN_addr,
                             D_SN_LOCAL_ADDR,
                             D_SN_QOS,
                             pdu);

end;

```

```

function pair_match : integer;

  (* match the D_IP_pair with s/d_ip_addr,
   set and return the index *)

var
  i,j,k,leng: integer;
  t: word_type;

begin
  j := 0;
  for i := 1 to D_IP_pair.last do    (* look for the pair with
                                       same IP_address info *)
    with D_IP_pair.buf[i] do
      if ((s_IP_addr = s_ip_addr) and
          (d_IP_addr = d_ip_addr)) then
        j := i;

    if ((j<>0) and (mod_id=0)) then      (* matched *)
      mod_id := D_IP_pair.buf[j].module/16;
    else if ((j<>0) and (mod_id<>0) and  (* matched *)
              (D_IP_pair.buf[j].module/16=0)) then

```

```

    D_IP_pair.buf[j].module := mod_id*16 + i_module_id;
else if (j=0) then      (* need fill in new IP_pair entry *)
begin
    if (D_IP_pair.last<MAX_QUEUE) then
        begin
            D_IP_pair.last := D_IP_pair.last+1;
            j := D_IP_pair.last;
        end;
    else
        (* no empty slot *)
        begin
            t := cur_time();
            for i := 1 to D_IP_pair.last do
                if (D_IP_pair.buf[i].timestamp<t) then
                    begin
                        j := i;
                        t := D_IP_pair.buf[i].timestamp;
                    end;
            end;

            pair_index := j;
            for k := 1 to segment_que.last do
                (* clean reassembly queue *)
                with segment_que.buf[k] do
                    send_ICMP(ICMP_SOURCE_QUENCH, 0, pdu);
                    (* send ICMP to report pdu lost *)
                end;
            end;

            with D_IP_pair.buf[j] do (* fill in *)
                begin
                    (* use empty/oldest slot *)
                    module = mod_id * 16 + i_module_id;
                    s_IP_addr := s_ip_addr;
                    d_IP_addr := d_ip_addr;
                    s_routing := d_null;
                    d_routing := d_null;
                    rcv_mes_que.last := 0;
                    send_mes_que.last := 0;
                    segment_que.last := 0;
                    timestamp = cur_time();
                end; (* with: fill in *)
            end; (* if j=0 *)

            pair_index := j;
            pair_match := j;
        end;

```

```

-      (***)
-      (***)      initialization      (***)
-      (***)      (***)

```

```

- initialize

```

```

-      pdu_error := 0;
-      icmp_unreachable := 0;
-      icmp_quench := 0;
-      icmp_exceeded := 0;
-      icmp_parameter := 0;
-
-      D_IP_pair.last := 0;
- end;

```

```

-      (***)
-      (***)      State Transition      (***)
-      (***)      (***)

```

```

- trans
-   when NET_INi.D_IP_PDUind      (* from DDN subnetwork *)

```

```

-       var
-         i,ii,j,k,leng,length,total: integer;
-         t: word_type;
-         pdu1: D_IP_PDU_type;
-         flag: FLAG_type;

```

```

-       begin
-         transit_time := cur_time();
-         cur_D_IP_pdu := packet;

```

```

-         s_ip_addr := cur_D_IP_pdu.source_addr;
-         d_ip_addr := cur_D_IP_pdu.destin_addr;
-         mod_id := 0;
-         j := pair_match();
-         err_flag := NO_ERROR;
-         s_route := d_null;
-         r_route := d_null;
-         with cur_D_IP_pdu do

```

```

-           with D_IP_pair.buf[j] do
-             begin
-               length := (I_length and 15) * 4;
-               if(chk_checksum(cur_D_IP_pdu,length)=false) then
-                 begin
-                   err_flag := ICMP_PARAM_PROBLEM;

```

```

err_num := 11;
end;
else
begin
lifetime := lifetime - D_LIFETIME;
leng := get_option_length(cur_D_IP_pdu);
opt_ptr := ^option;
while (leng>0) then
    if (opt_num(opt_ptr.code)=SOURCE_ROUTING) then
        begin
            s_route:=d_gets(opt_ptr,1,opt_ptr.length);
            s_routing := s_route;
        end;
    else if (opt_ptr.code=RECORD_ROUTING) then
        begin
            r_route := conv_routing(opt_ptr);
            r_routing := r_route;
        end;
    else
        begin
            k := one_option_length(opt_ptr.code);
            leng := leng - k;
            opt_ptr := ^opt_ptr + k;
        end;
    if((err_flag=NO_ERROR) and (lifetime<=0)) then
        begin
            err_flag := ICMP_TIME_EXCEEDED;
            err_num := ICMP_LIFETIME_EXCEEDED;
        end;
    else if((err_flag=NO_ERROR) and (s_route=d_null)) then
        begin
            err_flag := ICMP_DESTIN_UNREACHABLE;
            err_num := ICMP_SOURCE_ROUTING_FAILED;
        end;
end;

if (err_flag<>NO_ERROR) then (* send Error/Report *)
begin
send_ICMP(err_flag, err_code, cur_D_IP_pdu);
pdu_error := pdu_error+1; (* PDU dropped *)
end;
else
begin (* handle segment *)
flag := OK;
ii := 0;
if ((flags and MORE_FRAGMENT=0) and
(offset=0))then
begin
pdul := cur_D_IP_pdu; (* no segmentation *)
k := tot_length - (I_length and 15) * 4;
flag := COMPLETE;
end;
else
begin
i := 1;

```



```

while ((i<segment_que.last) and
      (id<segment_que.buf[i].pdu.id)) do
    i := i + 1;
ii := i;
k := 0;
if (offset=0) then      (* of cur_D_IP_pdu *)
    begin
        pdul := cur_D_IP_pdu;
        k := tot_length - (I_length and 15) * 4;
    end;
while ((flag=OK) and
      (i<segment_que.last) and
      (id=segment_que.buf[i].pdu.id)) do
    begin
        with segment_que.buf[i] do
            begin
                if (pdu.lifetime<=cur_time()- time) then
                    flag := EXPIRED;
                else if ( k < pdu.offset*8) then
                    flag := INCOMPLETE;
                else
                    begin
                        if (k=0) then
                            pdul := pdu;
                        else
                            d_append(pdul.data,pdu.data);
                            length := (pdu.I_length and 15)*4;
                            k := k + pdu.tot_length - length;
                        end;
                    end;
                if (k=8*offset) then      (* of cur_D_IP_pdu *)
                    begin
                        d_append(pdul.data, pdu.data);
                        length := (I_length and 15)*4;
                        k := k + tot_length - length;
                    end;
                if (flag=OK) then
                    i := i+1;
                else
                    (* stop *)
                    i := segment_que.last+1;
                end; (* while *)
            end; (* else *)
        end;
    if (((flag=OK) and (i=segment_que.last)) or
        (* miss last seg. *)
        (flag=INCOMPLETE)) then
        (* PDU is not complete yet *)
        begin
            (* queue cur_D_IP_pdu *)
            for k := segment_que.last to ii do
                segment_que.buf[k+1] := segment_que.buf[k];
            segment_que.buf[ii].pdu := cur_D_IP_pdu;
            segment_que.buf[ii].time := cur_time();
            segment_que.last := segment_que.last+1;
        end;
    else if (ii>0) then      (* need to extract segments
                               expired/reassembled *)

```

```

        while ((ii<segment_que.last) and
              (id=segment_que.buf[ii].pdu.id)) do
            begin
                exqueue(segment_que, ii);
                ii := ii+1;
            end;

    if (flag=EXPIRED) then
        send_ICMP(ICMP_TIME_EXCEEDED,
                 ICMP_REASSEMBLY_EXCEEDED,
                 cur_D_IP_pdu);
    else if(flag=COMPLETE) then
        begin
            with cur_IP_TP_mes do
                begin
                    module := D_IP_pair.buf[j].module;
                    mes_id := mes_id + 1;
                    if (mes_id=0) then
                        mes_id := 1;
                    message := mes_id;
                    s_IP_addr := s_ip_addr;
                    d_IP_addr := d_ip_addr;
                    data := pdu1.data;
                end;
            output NET_OUTi.D_IP_PDUind (cur_IP_TP_mes);

            with cur_IP_mes do
                begin
                    (* make GW packet *)
                    module := D_IP_pair.module;
                    message := mes_id;
                    source_addr := trans_d_ip_addr(s_ip_addr);
                    destin_addr := trans_d_ip_addr(d_ip_addr);
                    lifetime := trans_d_lifetime(pdu1.lifetime)
                               - (cur_time()-transit_time);
                    option := trans_d_option(pdu1.option);
                end;
            output NET_GWi.IP_MESind (cur_IP_mes);

            with cur_IP_handler do
                begin
                    (* make IP_message_handler *)
                    message := mes_id;
                    lifetime := pdu.lifetime;
                    option := pdu.option;
                end;
            enqueue (rcv_mes_que, cur_IP_handler);

            end; (* if flag *)
        end; (* else err_flag *)

    timestamp := cur_time;
end; (* with-with *)

end;

```

```

trans
  when NET_GWi.IP_MESreq          (* from GW common linker *)

    var
      j,leng,length: integer;

    begin
      cur_IP_mes := packet;
      with cur_IP_mes do
        begin
          mod_id := module/16 + (module mod 16)*16;
          d_ip_addr := trans_g_ip_addr(source_addr);
          s_ip_addr := trans_g_ip_addr(destin_addr);
          j := pair_match();
          with D_IP_pair.buf[j] do
            begin
              s_route := s_routing;
              r_route := r_routing;
              if ((s_route=d_null) or (r_route=d_null)) then
                begin
                  opt_ptr := ^option;
                  leng := d_length(option);
                  while (leng>0) then
                    if ((r_route=d_null) and
                      (opt_num(opt_ptr.code)=SOURCE_ROUTING)) then
                      begin
                        r_route:= conv_routing(opt_ptr);
                        r_routing := r_route;
                        end;
                    else if ((s_route=d_null) and
                      (opt_ptr.code=RECORD_ROUTING)) then
                      begin
                        s_route := d_gets(opt_ptr,1,opt_ptr.length);
                        s_routing := s_route;
                        end;
                    else
                      begin
                        k := one_option_length(opt_ptr.code);
                        leng := leng - k;
                        opt_ptr := ^opt_ptr + k;
                        end;
                  end; (* if *)
                with cur_IP_handler do
                  begin
                    (* make IP_message_handler *)
                    message := mes_id;
                    lifetime := trans_g_lifetime(cur_IP_mes.lifetime);
                    option := trans_g_option(cur_IP_mes.option);
                    in_time := cur_time();
                    end;
                  enqueue (send_mes_queue, cur_IP_handler);
                  timestamp := cur_time;
                end; (* with D_IP_pair.buf[j] *)
              end; (* with cur_IP_mes *)
            end;
          end;
        end;
      end;
    end;
  end;

```

```

trans
  when NET_OUTi.D_IP_PDureq                                (* from TCP *)

  var
    i,j,k,n: integer;
    handler: IP_message_handler_type;
    ip_data: data_type;

  begin
    cur_IP_TP_mes := packet;
    with cur_IP_TP_mes do
      begin
        mod_id := module/16 + (module mod 16)*16;
        mes_id := message;
        s_ip_addr := d_IP_addr;
        d_ip_addr := s_IP_addr;

        j := 0;
        for i := 1 to D_IP_pair.last do
          with D_IP_pair.buf[i] do
            if ((s_ip_addr=s_IP_addr) and
                (d_ip_addr=d_IP_addr)) then
              j := i;

          if (j=0) then
            pdu_error := pdu_error+1;
            (* It is supposed to have a match here
               because even if the IP_module at the
               gateway side initiated the session, the
               IP_message has been transferred over
               faster to establish an entry earlier. *)
          else
            with D_IP_pair.buf[j] do
              begin
                pair_index := j;                                (* global *)
                k := 0;
                if (mes_id<>0) then
                  for i:= 1 to send_mes_que.last do
                    if (send_mes_que.buf[i].message=mes_id) then
                      k := i;
                  if (k=0) then
                    k := 1;      (* if no match, use 1st one *)
                handler := exqueue(send_mes_que, k);
                with cur_D_IP_pdu do
                  begin
                    service := 0;
                    destin_addr := s_ip_addr;
                    source_addr := d_ip_addr;
                    id := get_data_unit_id;
                    flags := 0;
                    offset := 0;
                    protocol := TCP_PROTOCOL;
                    lifetime := handler.lifetime
                      - (cur_time() - handler.in_time);

```

```

option := handler.option;
I_length := d_length(option)/4 + 5;
data := cur_IP_TP_mes.data;

(* segmentation & output *)
n := d_length(data);
if (n > D_IP_MAX_SEGMENT_LENGTH) then
begin
  ip_data := data;
  i := 1;
  while (n > i * D_IP_MAX_SEGMENT_LENGTH) do
begin
  flags := flags or MORE_FRAGMENT;
  offset := offset +
    D_IP_MAX_SEGMENT_LENGTH/8;
  data := d_gets(ip_data,
    (i-1)*D_IP_MAX_SEGMENT_LENGTH+1,
    D_IP_MAX_SEGMENT_LENGTH);
  if(i=2) then
    copy_options();
  one_segment(cur_D_IP_pdu);
  i := i+1;
  n := d_length(ip_data);
end;
  flags := flags and (not MORE_FRAGMENT);
  data:=d_gets(ip_data,
    (i-1)*D_IP_MAX_SEGMENT_LENGTH+1,
    d_length(ip_data)
    -D_IP_MAX_SEGMENT_LENGTH);
end; (* if n > *)

  one_segment();
end; (* with cur_D_IP_pdu *)
timestamp := cur_time;
end; (* with D_IP_pair.buf[j] *)
end; (* with cur_IP_TP_mes *)
end; (* trans *)

end; (* of DDN_IP_entity_body *)

```

APPENDIX A.3 TRANSPORT_LAYER MODULE SPECIFICATION

```
( ***                                     *** )  
( ***      TRANSPORT_LAYER Module Specification      *** )  
( ***                                     *** )
```

body TRANSPORT_LAYER_entity_body for TRANSPORT_LAYER_entity_type;

constant

```
MAX_CONN = ...;          (* Max Transport Connections *)  
  
CR_VAR = 7;              (* position of varriable part *)  
DC_VAR = 6;              (* for CR, CC, DR *)  
DT_VAR = 5;              (* for DC *)  
DTe_VAR = 8;             (* for DT, ED, AK, EA, ER *)  
                           (* for DTe, EDe, AKe, EAe *)  
  
EDCODE = 1;              (* TPDU code *)  
EACODE = 2;  
RJCODE = 5;  
AKCODE = 6;  
ERCODE = 7;  
DRCODE = 8;  
DCCODE = 12;  
CCCODE = 13;  
CRCODE = 14;  
DTCODE = 15;  
  
CLASS_0 = 0;             (* Class of Transport Service *)  
CLASS_1 = 1;  
CLASS_2 = 2;  
CLASS_3 = 3;  
CLASS_4 = 4;  
  
CALINGCODE = 193;        (* Calling TSAP ID *)  
CALLEDCODE = 194;        (* Called TSAP ID *)  
PDUSIZCODE = 192;        (* max TPDU size, 7..13 = 128..8,192 *)  
VERSNOCODE = 196;        (* version No., value=1 *)  
SECURICODE = 197;        (* user-def protection parameter *)  
CHKSUMCODE = 195;        (* checksum, in CLASS_4 only *)  
ADDLOPCODE = 198;        (* additional options,  
                           2:no checksum, 1:use ED *)  
  
ALTCLSCODE = 199;        (* alternative Class *)  
AKTIMECODE = 133;        (* short_word of max ack time, in ms *)  
THRUPTCODE = 137;        (* throughput *)  
RESERRCODE = 134;        (* residual error *)  
PRIORTCODE = 135;        (* priority *)  
TRNDELCODE = 136;        (* Transit delay *)  
REASSGCODE = 139;        (* reassignment time *)
```

```

SUBSEQCODE = 138;      (* sub-sequence number *)
FLOCONCODE = 140;      (* flow control confirmation *)

```

```

R_not_specified = 0;    (* reasons *)
R_TSAP_congestion = 1;
R_address_unknown = 3;
R_user_normal = 128;
R_peer_congestion = 129;
R_negotiation_failed = 130;
R_duplicate_src_ref = 131;
R_ref_mismatched = 132;
R_protocol_error = 133;
R_not_used = 134;
R_ref_overflow = 135;
R_CR_refused = 136;
R_not_used = 137;
R_invalid_hdr_param_length = 138;

```

type

```

retrans_type = record
    timer : integer;      (* time left before retrans *)
    count : integer;      (* count of retrans *)
    data : data_type;     (* PDU *)
end;

```

```

reorder_type = record
    seq : integer;        (* sequence number for re-order *)
    data : data_type;     (* PDU *)
end;

```

```

TP_param_type = (CALINGCODE, CALLEDCODE, PDUSIZCODE, VERSNOCODE,
                 SECURICODE, CHKSUMCODE, ADDLOPCODE, ALTCLSCODE,
                 AKTIMECODE, THRUPTCODE, RESERRCODE, PRIORTCODE,
                 TRNDELCODE, REASSGCODE);

```

```

TP_var_part_type = record
    param_code : TP_param_type; (* parameter code *)
    length      : octet;         (* length indicator *)
    value       : data_type;     (* parameter value *)
end;
(* the data structure defined here is for the
   variable part of the TPDU. Some kinds of TPDU's
   can have multiple parameters whose total length
   can be decided indirectly by the length of the
   TPDU header. *)

```

throughput_type = record

```
max_AB : integer;      (* maximum *)
min_AB : integer;      (* max. calling - called *)
max_BA : integer;      (* min. *)
min_BA : integer;      (* max. called - calling *)
ave_AB : integer;      (* min. *)
a_min_AB : integer;    (* average *)
ave_BA : integer;
a_min_BA : integer;
end;
```

residual_error_type = record

```
target : integer;
min_acc : integer;
TSDU_size : integer;
end;
```

transit_delay_type = record

```
target_AB : integer;
max_AB : integer;
target_BA : integer;
max_BA : integer;
end;
```

TPDU_code_type = (EDCODE, EACODE, RJCODE, AKCODE, ERCODE,
DRCODE, DCCODE, CCCODE, CRCODE, DTCODE);

TP_class_type = (CLASS_0, CLASS_1, CLASS_2, CLASS_3,
CLASS_4);

TP_reason_type = (R_not_specified, R_TSAP_congestion,
R_address_unknown, R_user_normal,
R_peer_congestion, R_negotiation_failed,
R_duplicate_src_ref, R_ref_mismatched,
R_protocol_error, R_not_used,
R_ref_overflow, R_CR_refused,
R_not_used, R_invalid_hdr_param_length);


```

TPDU_message_type = record
    module      : octet;          (* Module Id *)
    message     : octet;          (* Message Id *)
    s_IP_addr   : word_type;      (* source IP address *)
    d_IP_addr   : word_type;      (* destin IP address *)
    tpdu_code   : TPDU_code_type; (* TPDU code *)
    dst_ref     : short_word;     (* GW desti_refrence *)
    src_ref     : short_word;     (* GW source_refrence *)
    class       : TP_class_type;  (* Class option *)
    reason      : TP_reason_type; (* reason/reject_cause *)
    v_length    : octet;          (* var_part length *)
    var_part    : TP_var_part_type; (* variable part *)
    d_length    : integer;        (* data length *)
    data        : data_type;      (* user data *)
end;

```

(* The data structure defined above is used for the communication between the Transport Layer protocol-dependent submodules and the common linker module.

One point to notice is that the format is close to the ISO TPDU structure. It is chosen because the ISO TP data structures have more capacity than those of DoD TCP, except for the Urgent Data. So it is quite reasonable to use the format closer to the standard one. The Urgent Data problem will be solved in some strategic way such as using the Expedited Data to transfer the Urgent Data.

Another point to notice is that both the sequence number and the credit are removed from the data structure. The reason behind is that these two control parameters are local significant only. Each side of the gateway will have independent control over them.
*)

```

(***                                     ***)
(***             Module Interaction Points             ***)
(***                                     ***)

```

```

(* TP Transport Gateway Interaction Point (to linker) *)

```

```

channel TP_linker_primitives (user, provider);

```

```

by user:

```

```

    TP_MESreq (message : TPDU_message_type);

```

```

by provider:

```

```

    TP_MESind (message : TPDU_message_type);

```

```

(***                                     ***)
(***             Submodule Definitions             ***)
(***                                     ***)

```

```

module ISO_TP4_entity_type process

```

```

    (NSi: NCEP_primitives (user,provider);

```

```

    TGi: TP_linker_primitives (user,provider);

```

```

    );

```

```

export

```

```

    tp4_module_id: integer;      (* ISO TP module id *)

```

```

    inet_sent: integer;          (* packets sent to ISO IP *)

```

```

    inet_rcved: integer;         (* packets received from ISO IP *)

```

```

    inet_error: integer;         (* errors in packets with ISO IP *)

```

```

end;

```

```

module DDN_TCP_entity_type process

```

```

    (NSd: NCEP_primitives (user,provider);

```

```

    TGd: TP_linker_primitives (user,provider);

```

```

    );

```

```

export

```

```

    tcp_module_id: integer;      (* DDN TCP module id *)

```

```

    dnet_sent: integer;          (* packets sent to DDN IP *)

```

```

    dnet_rcved: integer;         (* packets received from DDN IP *)

```

```

    dnet_error: integer;         (* errors in packets with DDN IP *)

```

```

end;

```

```

body ISO_TP4_entity_body for ISO_TP4_entity_type; external;

```

```

body DDN_TCP_entity_body for DDN_TCP_entity_type; external;

```

```

(***)
(***)      initialization      (***)
(***)
(***)

```

initialize

```

init ISO_TP4 with ISO_TP4_entity_body();
attach NSi to ISO_TP4.NSi;      (* with ISO IP *)
connect TGi to ISO_TP4.TGi;
ISO_TP4.tp4_module_id := 9;
ISO_TP4.inet_rcved := 0;
ISO_TP4.inet_sent := 0;
ISO_TP4.inet_error := 0;

init DDN_TCP with DDN_TCP_entity_body();
attach NSd to DDN_TCP.NSd;      (* with DDN IP *)
connect TGd to DDN_TCP.TGd;
DDN_TCP.tcp_module_id := 10;
DDN_TCP.dnet_rcved := 0;
DDN_TCP.dnet_error := 0;
DDN_TCP.dnet_error := 0;
end;

```

```

(***)
(***)      State Transition      (***)
(***)
(***)

```

```

trans
  when TGi.TP_MESind      (* from ISO_TP4 to Common Linker *)
  begin
    output TGd.TP_MESreq(packet);  (* send to DDN_TCP *)
  end;

```

```

trans
  when TGd.TP_MESind      (* from DDN_TCP to Common Linker *)
  begin
    output TGi.TP_MESreq(packet);  (* send to ISO_TP4 *)
  end;

```

```

end;      (* The End of TRANSPORT_LAYER module (Common Linker) *)

```

APPENDIX A.3.1 ISO_TP4 SUBMODULE

```
(***                                     ***)
(***)      ISO_TP4 Submodule Specification      (***)
(***)                                     (***)
```

```
body ISO_TP4_entity_body for ISO_TP4_entity_type;
```

```
(***                                     ***)
(***)      TP4 Interface Interaction Point      (***)
(***)                                     (***)
```

```
(* TP-4 State Machine Interaction Point *)
```

```
channel TP4_machine_primitives (user, provider);
```

```
by provider:
```

```
TP4M_MESind (message : IP_TP_message_type);
              (* send TPDUs to TP4_machine *)
```

```
by user:
```

```
TP4M_MESreq (message : IP_TP_message_type);
              (* TP4_machine sends TPDUs out *)
```

```
(* TP Transport Gateway Interaction Point (to linker module) *)
```

```
channel TP4_interface_primitives (user, provider);
```

```
by provider:
```

```
TP4I_MESind (message : IP_TP_message_type);
```

```
by user:
```

```
TP4I_MESreq (message : IP_TP_message_type);
```

```

(***                                     ***)
(***      TP4 State Machine SubModule Specification      ***)
(***                                     ***)

```

```

module TP4_machine_type process
    (TP4M_I: TP4_machine_primitives (user);
     TP4M_O: TP4_machine_primitives (provider);
     TP4I_I: TP4_interface_primitives (user);
     TP4I_O: TP4_interface_primitives (provider);
    );
export
    state      : TP4_state_type; (* connection state *)
    l_module   : octet;          (* local module id *)
    g_module   : octet;          (* GW module id *)
    d_ip_addr  : word_type;      (* destination IP address *)
    s_ip_addr  : word_type;      (* source IP address *)
    l_ref      : short_word;     (* local reference *)
    r_ref      : short_word;     (* remote reference *)
    g_ref      : short_word;     (* gateway cross reference *)
    ex_flag    : boolean;        (* extended format *)
    ch_flag    : boolean;        (* checksum flag *)
    ed_flag    : boolean;        (* expedited data service *)
    class      : octet;          (* class and flags *)
end;

```

```

body TP4_machine_body for TP4_machine_type; external;

```

```

-      (***)
-      (***)   variables of the ISO_TP4_body   (***)
-      (***)                                     (***)

```

```

-  var

```

```

-      total_conn : integer;      (* total active transport conn *)
-      conn_flag   : array [1..MAX_CONN] of boolean;
-                                     (* slot available flag *)
-      TP4M        : array [0..MAX_CONN] of TP4_machine_type;
-                                     (* instance of TP4_machine *)
-
-      cur_conn: integer;          (* cur connection reference *)
-      direction : direction_type; (* cur mes flow direction *)
-      cur_mod_id : octet;         (* module Id *)
-      cur_mes_id : octet;         (* message Id *)
-      cur_mes : IP_TP_message_type; (* cur IP_TP message *)
-      cur_tpdu : TPDU_type;       (* TPDU, used as pointer *)
-      cur_s_IP : word_type;       (* source IP address *)
-      cur_d_IP : word_type;       (* destin IP address *)
-      cur_tpdu_code : TPDU_code_type; (* current TPDU code *)
-      flag_extended: boolean;     (* flag for extended format *)
-      calling_tsap, called_tsap: short_word;
-
-      total_mes : integer;        (* total messages going through *)
-      err_mes : integer;          (* messages with error conditions *)
-      fatal_err : integer;        (* fatal errors *)

```

```

(***                                     ***)
(*** Common Procedures of ISO_TP4_body *** )
(***                                     ***)

```

```
function conn_alloc : integer;
```

```
  (* allocate a free slot of connection *)
```

```
  var
```

```
    i,j : integer;
```

```
  begin
```

```
    j := 0;
```

```
    if (total_conn < MAX_CONN) then
```

```
      for i := MAX_CONN to 1 do
```

```
        if (conn_flag[i] = false) then
```

```
          j := i;
```

```
    if (j > 0) then
```

```
      begin
```

```
        total_conn := total_conn+1;
```

```
        conn_flag[j] := true;
```

```
      end;
```

```
    conn_alloc := j;
```

```
  end;
```

```

(* In the case of (total_conn=MAX_CONN), (conn_alloc=0) will be
returned. There exists a TP4M[0] to be used in this case to
respond to abnormal TPDUs. *)

```

```
procedure conn_free (j : integer); (* free the connection slot *)
```

```
  begin
```

```
    if ((j>0) and (j<=MAX_CONN)) then
```

```
      if (conn_flag[j] = true) then
```

```
        begin
```

```
          conn_flag[j] := false;
```

```
          total_conn := total_conn-1;
```

```
        end;
```

```
    end;
```

```
function TP4_code (TPDU: TPDU_type): TPDU_code_type;
```

```
  (* check the TPDU_code of the TPDU *)
```

```
  begin
```

```
    TP4_code := TPDU[2] / 16;
```

```
    (* 4 bits at left *)
```

```
  end;
```

```

function cur_TP4_code (mes: IP_TP_message) : TPDU_code_type;

    (* check the TPDU_code of the 1st IP_TP message in queue *)

begin
    cur_mes := mes;                                (* access NQ message *)
    cur_tpdu := cur_mes.data;                        (* point to TPDU *)
    cur_conn := cur_tpdu.dst_ref;                    (* TCP reference index *)
    cur_tpdu_code := TP4_code(cur_tpdu);             (* get the TPDU code *)
    if (cur_tpdu_code <> CRCODE) then
        flag_extended := TP4M[cur_conn].ex_flag; (* ext.ed format *)
    cur_TP4_code := cur_tpdu_code;
end;

function tpdu_fixed : integer;

    (* get the pointer to the variable part in cur_tpdu *)

var
    i, l: integer;

begin
    l := cur_tpdu[1];                                (* get Length Indicator *)
    case cur_tpdu_code of
        CRCODE, CCCODE, DRCODE:
            i := CR_VAR;                                (* point to variable part *)
        DCCODE:
            i := DC_VAR;
        DTCODE, AKCODE, EDCODE, EACODE, ERCODE:
            begin
                i := DT_VAR;
                if (flag_extended) then
                    i := i+3;
                end;
            end;
    end;
    tpdu_fixed := i;
end;

```



```

function tpdu_acceptable (mes: IP_TP_message_type) : boolean;

    (* check the TPDU to see if it is acceptable *)

var
    ok,checksum: boolean;
    i,j,k,l: integer;

begin
    checksum := false;
    ok := true;
    cur_TP4_code(mes);  (* get cur_conn, cur_TP_code, etc. *)

    if (cur_conn<>0) then
        begin
            if (con_flag[cur_conn]=false) then
                ok := false;
            else
                begin
                    if (TP4M[cur_conn].g_module=0) then
                        TP4M[cur_conn].g_module = cur_mes.module/16;
                    else
                        if(TP4M[cur_conn].g_module<>cur_mes.module/16) then
                            ok := false;

                    if (TP4M[cur_conn].d_ip_addr=0) then
                        TP4M[cur_conn].d_ip_addr:=cur_mes.d_IP_addr;
                    else
                        if(TP4M[cur_conn].d_ip_addr<>cur_mes.d_IP_addr)
                            then
                                ok := false;

                    if (TP4M[cur_conn].s_ip_addr=0) then
                        TP4M[cur_conn].s_ip_addr:=cur_mes.s_IP_addr;
                    else
                        if(TP4M[cur_conn].s_ip_addr<>cur_mes.s_IP_addr)
                            then
                                ok := false;

                    if(TP4M[cur_conn].r_ref=0) then
                        TP4M[cur_conn].r_ref := cur_tpdu.src_ref;
                    else if (cur_tpdu.src_ref<>TP4M[cur_conn].r_ref) then
                        ok := false;                (* check the SRC_REF *)
                end;
            end;

        if ((ok) and (cur_tpdu_code <> RJCODE)) then
            begin
                i := tpdu_fixed();                (* length of fixed part *)
                l := cur_tpdu[1]-i+1;              (* No of bytes left,
                                                    LI exclude itself *)
                i := i+1;                          (* point to variable part *)
                while (l>0) do
                    begin                          (* check valid var. part *)

```

```

        if (cur_tpdu[i]=CHKSUMCODE) then
            checksum := true;      (* there exists checksum *)
            j := cur_tpdu[i+1];    (* get the length of field *)
            l := l-j-2;
            i := i+j+2;
        end;
        if ((ok) and (l<0)) then    (* error in variable part *)
            ok := false;

        if ((ok) and (checksum)) then
            ok := chk_checksum(cur_tpdu, cur_tpdu.length);
                                   (* check the checksum *)
        end;

    tpdu_acceptable := ok;
end;

function dup_CR (mes: IP_TP_message_type) : boolean;

    (* check the CR TPDU to see if it is duplicate *)

var
    dup: boolean;
    CR_tpdu: TPDU_CR_type;
    i: integer;

begin
    CR_tpdu := mes.data;
    cur_conn := 0;
    dup := false;
    i := 1;
    while ((i<=MAX_CONN) and (dup=false)) do
        begin
            if ((conn_flag[i]=true) and
                (mes.s_IP_addr=TP4M[i].s_ip_addr) and
                (mes.d_IP_addr=TP4M[i].d_ip_addr) and
                (CR_tpdu.src_ref=TP4M[i].r_ref)) then
                begin
                    cur_conn := i;
                    dup := true;
                end;
            i := i+1;
        end;
    dup_CR := dup;
end;

```

```

function dup_CRg (mes: TPDU_message_type) : boolean;

    (* check the CR TPDU from TP_GW to see if it is duplicate *)

var
    dup: boolean;
    i: integer;

begin
    cur_conn := 0;
    dup := false;
    i := 1;
    while((i<=MAX_CONN) and (dup=false)) do
        begin
            if ((conn_flag[i]=true) and
                (mes.d_IP_addr=TP4M[i].s_ip_addr) and
                (mes.s_IP_addr=TP4M[i].d_ip_addr) and
                (mes.src_ref=TP4M[i].g_ref)) then
                begin
                    cur_conn := i;
                    dup := true;
                end;
            i := i+1;
        end;
    dup_CRg := dup;
end;

```

```

    (***)
    (***)      Initialization of ISO_TP4_body      (***)
    (***)
(***)
initialize

    total_mes := 0;          (* total messages *)
    err_mes := 0;           (* error messages *)
    fatal_err := 0;         (* fatal errors *)

    total_conn := 0;         (* total transport connections *)
    for i := 1 to MAX_CONN do
        conn_flag := false; (* the connection slot is free *)

    init TP4M[0] with TP4_machine_interface_body();
                                (* virtual State_machine for
                                responding to error CR's *)

    TP4M[0].l_ref := 0;
    connect TP4M_I to TP4M[0].TP4M_I;
    connect TP4I_I to TP4M[0].TP4I_I;
    attach TP4M_O to TP4M[0].TP4M_O;
    attach TP4I_O to TP4M[0].TP4I_O;

end;

```

```

(***)
(***)      State Transitions      (***)
(***)
(***)

```

```

trans
  when NSi.IP_TP_MESind priority 0      (* receive from ISO-IP *)

```

```

  begin
    total_mes := total_mes+1;
    direction := in;

    if (tpdu_acceptable(message)=false) then
      err_mes := err_mes+1;      (* TPDU not acceptable *)
    else if (cur_tpdu_code=CRCODE) then (* and cur_conn=0 *)
      begin      (* Connection Request *)
        if (dup_CR(message)=false) then
          begin
            cur_conn := conn_alloc();
            if (cur_conn>0) then
              begin      (* initialize TP4 protocol
                           machine *)
                init TP4M[cur_conn] with
                  TP4_machine_interface_body();
                with TP4M[cur_conn] do
                  begin
                    l_ref := cur_conn;
                    flag_kill_me := conn_in_progress;
                  end;
                  connect TP4M_I to TP4M[cur_conn].TP4M_I;
                  connect TP4I_I to TP4M[cur_conn].TP4I_I;
                  attach TP4M_O to TP4M[cur_conn].TP4M_O;
                  attach TP4I_O to TP4M[cur_conn].TP4I_O;
                end;      (* if conn *)
              end;      (* if dup_CR *)
            output TP4M[cur_conn].TP4M_I(message);
            (* pass TPDU for further check or response *)
          end;      (* if CR *)
        else
          output TP4M[cur_conn].TP4M_I(message);
        end;      (* trans *)
      end;

```

```

(* For duplicated CR, the state machine TP4M[cur_conn] will
   response to it with CC, as required by ISO 8073.

```

```

In case there is no local connection slot available,
cur_conn is reset to 0 by dup_CR(), or by conn_alloc(), the
CR will be passed to TP4M[0] which will in turn send a DR to
refuse the connection request. *)

```

```

trans
  when TGS.TP_MESreq priority 0      (* receive from TCP, before
                                     feeding into TP4_machine *)

    begin
      total_mes := total_mes+1;
      direction := out;
      cur_mes := message;
      cur_tpdu := cur_mes.data;      (* point to TPDU *)
      cur_conn := cur_tpdu.src_ref;  (* TCP reference index *)
      flag_extended := TP4M[cur_conn].class and 2; (* extended format *)
      cur_tpdu_code := TP4_code(cur_tpdu); (* get the TPDU code *)
      case cur_tpdu_code of
        CCCODE,DRCCODE,DCCODE,DTCCODE,
        AKCODE,EDCODE,EACODE,ERCODE,
        RJCODE :
          output TP4M[cur_conn].TP4I_I(message);

        CRCODE :
          begin
            if (dup_CRg(message)=false) then
              begin
                cur_conn := conn_alloc();
                if (cur_conn>0) then
                  begin (* initialize a new TP4_machine *)
                    init TP4M[cur_conn] with
                      TP4_machine_interface_body();
                    with TP4M[cur_conn] do
                      begin
                        l_ref := cur_conn;
                        flag_kill_me := conn_in_progress;
                      end;
                      connect TP4M_I to TP4M[cur_conn].TP4M_I;
                      connect TP4I_I to TP4M[cur_conn].TP4I_I;
                      attach TP4M_O to TP4M[cur_conn].TP4M_O;
                      attach TP4I_O to TP4M[cur_conn].TP4I_O;
                      end; (* if conn *)
                    end; (* if *)
                  output TP4M[cur_conn].TP4I_I(message);
                  (* pass TPDU for further checking *)
                end; (* case CR *)
              end; (* case *)
            end; (* trans *)
          end;
    end;

```

```

trans
  any TP4M[i]: TP4_machine_interface_type do
    provided (TP4M[i].flag_kill_me = now) priority 1
      begin
        disconnect TP4M[i].TP4M_I; (* disconnect port relations *)
        disconnect TP4M[i].TP4I_I;
        detach TP4M[i].TP4M_O;
        detach TP4M[i].TP4I_O;
        release TP4M[i]; (* terminate TP4_machine *)
        conn_free(i); (* free the slot for future use *)
      end;
end; (* of ISO_TP4_body *)

```

```

(***                                     ***)
(***   TP4_machine_interface_body   Specification   ***)
(***                                     ***)

```

```

body TP4_machine_interface_body for TP4_machine_interface_type;

```

```

constant

```

```

    VERSION = 1;                                (* TP-4 version, IS 8073 *)

```

```

type

```

```

    (* TPDU formats *)

```

```

    TPDU_type: data_type;                        (* general form *)

```

```

    TPDU_CR_type = record                        (* for CR, CC *)
        length      : octet;                    (* length indicator *)
        tpdu_code   : TPDU_code_type;          (* TPDU code and CDT *)
        dst_ref     : short_word;              (* destin_refrence *)
        src_ref     : short_word;              (* source_refrence *)
        class       : TP_class_type;           (* Class option *)
        var_part    : TP_var_part_type;        (* variable part *)
        data        : data_type;               (* user data *)
    end;

```

```

    TPDU_DR_type = record                        (* for DR *)
        length      : octet;                    (* length indicator *)
        tpdu_code   : TPDU_code_type;          (* TPDU code *)
        dst_ref     : short_word;              (* destin_refrence *)
        src_ref     : short_word;              (* source_refrence *)
        reason      : TP_reason_type;          (* reason *)
        var_part    : TP_var_part_type;        (* variable part *)
        data        : data_type;               (* user data *)
    end;

```

```

    TPDU_DC_type = record                        (* for DC *)
        length      : octet;                    (* length indicator *)
        tpdu_code   : TPDU_code_type;          (* TPDU code *)
        dst_ref     : short_word;              (* destin_refrence *)
        src_ref     : short_word;              (* source_refrence *)
        var_part    : TP_var_part_type;        (* variable part *)
    end;

```



```

TPDU_DT_type = record                                (* for DT, ED *)
    length      : octet;                             (* length indicator *)
    tpdu_code   : TPDU_code_type;                    (* TPDU code *)
    dst_ref     : short_word;                        (* destin_refrence *)
    seq_no      : octet;                             (* sequence no and EOT *)
    var_part    : TP_var_part_type;                 (* variable part *)
    data        : data_type;                         (* user data *)
end;

```

```

TPDU_DTe_type = record                              (* for extended DT, ED *)
    length      : octet;                             (* length indicator *)
    tpdu_code   : TPDU_code_type;                    (* TPDU code *)
    dst_ref     : short_word;                        (* destin_refrence *)
    seq_no      : word_type;                         (* sequence no and EOT *)
    var_part    : TP_var_part_type;                 (* variable part *)
    data        : data_type;                         (* user data *)
end;

```

```

TPDU_AK_type = record                              (* for AK, EA *)
    length      : octet;                             (* length indicator *)
    tpdu_code   : TPDU_code_type;                    (* TPDU code and CDT *)
    dst_ref     : short_word;                        (* destin_refrence *)
    seq_no      : octet;                             (* sequence no and EOT *)
    var_part    : TP_var_part_type;                 (* variable part *)
end;

```

```

TPDU_AKe_type = record                             (* for extended AK *)
    length      : octet;                             (* length indicator *)
    tpdu_code   : TPDU_code_type;                    (* TPDU code *)
    dst_ref     : short_word;                        (* destin_refrence *)
    seq_no      : word_type;                         (* sequence no *)
    cdt         : short_word;                        (* credit *)
    var_part    : TP_var_part_type;                 (* variable part *)
end;

```

```

TPDU_EAe_type = record                             (* for extended EA *)
    length      : octet;                             (* length indicator *)
    tpdu_code   : TPDU_code_type;                    (* TPDU code *)
    dst_ref     : short_word;                        (* destin_refrence *)
    seq_no      : word_type;                         (* sequence no *)
    var_part    : TP_var_part_type;                 (* variable part *)
end;

```

```

TPDU_RJ_type = record                              (* for RJ *)
    length      : octet;                             (* length indicator *)
    tpdu_code   : TPDU_code_type;                    (* TPDU code and CDT *)
    dst_ref     : short_word;                        (* destin_refrence *)
    seq_no      : octet;                             (* sequence no and EOT *)
end;

```


| | | |
|------------------------|---------------------------|---|
| mes_DTe_type = record | (* for extended DT, ED *) | - |
| module : octet; | (* Module Id *) | |
| message : octet; | (* Message Id *) | |
| s_IP_addr : word_type; | (* source IP address *) | - |
| d_IP_addr : word_type; | (* destin IP address *) | |
| tpdu : TPDU_DTe_type; | (* DTe TPDU *) | |
| end; | | - |
| | | |
| mes_AK_type = record | (* for AK, EA *) | |
| module : octet; | (* Module Id *) | - |
| message : octet; | (* Message Id *) | |
| s_IP_addr : word_type; | (* source IP address *) | |
| d_IP_addr : word_type; | (* destin IP address *) | - |
| tpdu : TPDU_AK_type; | (* AK TPDU *) | |
| end; | | - |
| | | |
| mes_AKe_type = record | (* for extended AK *) | |
| module : octet; | (* Module Id *) | - |
| message : octet; | (* Message Id *) | |
| s_IP_addr : word_type; | (* source IP address *) | |
| d_IP_addr : word_type; | (* destin IP address *) | - |
| tpdu : TPDU_AKe_type; | (* AKe TPDU *) | |
| end; | | - |
| | | |
| mes_EAe_type = record | (* for extended EA *) | - |
| module : octet; | (* Module Id *) | |
| message : octet; | (* Message Id *) | - |
| s_IP_addr : word_type; | (* source IP address *) | |
| d_IP_addr : word_type; | (* destin IP address *) | - |
| tpdu : TPDU_EAe_type; | (* EAe TPDU *) | |
| end; | | - |
| | | |
| mes_RJ_type = record | (* for RJ *) | - |
| module : octet; | (* Module Id *) | |
| message : octet; | (* Message Id *) | |
| s_IP_addr : word_type; | (* source IP address *) | - |
| d_IP_addr : word_type; | (* destin IP address *) | |
| tpdu : TPDU_RJ_type; | (* RJ TPDU *) | |
| end; | | - |
| | | |
| mes_RJe_type = record | (* for extended RJ *) | |
| module : octet; | (* Module Id *) | - |
| message : octet; | (* Message Id *) | |
| s_IP_addr : word_type; | (* source IP address *) | |
| d_IP_addr : word_type; | (* destin IP address *) | - |
| tpdu : TPDU_RJe_type; | (* RJe TPDU *) | |
| end; | | - |

```

mes_ER_type = record
    module      : octet;
    message     : octet;
    s_IP_addr   : word_type;
    d_IP_addr   : word_type;
    tpdu        : TPDU_ER_type;
end;

```

(* for ER *)
 (* Module Id *)
 (* Message Id *)
 (* source IP address *)
 (* destin IP address *)
 (* ER TPDU *)

```

TP4_state_type = (CLOSED, OPEN, WFCCiso, WFCCout, AKWAITiso,
                  AKWAITout, CLOSINGiso, CLOSINGout, REFWAIT);

```

```

(***)
(***) Variables of TP4_machine_interface_body (***)
(***)

```

var

```

proto_err : integer;      (* fatal errors *)
l_TSAP    : short_word;   (* local TSAP id *)
r_TSAP    : short_word;   (* remote TSAP id *)
initiator : initiator_type; (* who initiate the conn *)
size      : octet;        (* max TPDU size *)
vers      : octet;        (* TP version *)
prot      : data_type;    (* user-def protection *)
ack_time  : short_word;   (* max ack time in msec *)
throuput  : throughput_type; (* throuput *)
res_error : res_error_type; (* residual error *)
priority  : short_word;   (* priority *)
trans_delay: trans_delay_type; (* transit delay *)
g_class   : octet;        (* GW class and flags *)
g_size    : octet;        (* GW max TPDU size *)
g_vers    : octet;        (* GW TP version *)
g_prot    : data_type;    (* GW user-def protection *)
g_ack_time: short_word;   (* GW max ack time in msec *)
g_throuput: throughput_type; (* GW throuput *)
g_res_error: res_error_type; (* GW residual error *)
g_priority: short_word;   (* GW priority *)
g_trans_delay: trans_delay_type; (* GW transit delay *)
send_seq  : word_type;    (* sending sequence no *)
send_cdt  : short_word;   (* sending credit *)
s_sub_seq : short_word;   (* sub-seq no for AK *)
s_ack_seq : word_type;    (* ack_ed sequence no *)
rcv_seq   : word_type;    (* receiving sequence no *)
rcv_cdt   : short_word;   (* receiving credit *)
r_sub_seq : short_word;   (* sub-seq no for AK *)
r_ack_seq : word_type;    (* ack_ed sequence no *)

exp_flag  : boolean;      (* flag for ED blocking *)
exp_seq   : integer;      (* ED sequence number *)
exp_que   : queue_type of data_type; (* blocked DTs *)

reason    : TP_reason_type; (* reason *)
cause     : TP_cause_type;  (* Reject cause *)
re_trans  : queue_type of retrans_type; (* retransmission *)
re_order  : queue_type of reorder_type; (* re-order *)

cur_mes   : IP_TP_message_type; (* cur IP_TP message *)
cur_tpdu  : TPDU_type;          (* TPDU, used as pointer *)
cur_tpdu_code : TPDU_code_type; (* current TPDU code *)
var_ptr   : ^TP_var_part_type; (* ptr to variable part *)
sub_state : boolean;           (* associated flag *)
seq       : word_type;
cdt       : short_word;

```

```

msg CR, msg CC : msg CR type;  (* various kinds of message *)
msg DT, msg ED : msg DT type;
msg AK, msg EA : msg AK type;
msg DTs, msg EDe : msg DTs type;
msg AKs, msg EAs : msg AKs type;
msg DR : msg DR type;
msg DC : msg DC type;
msg RJ : msg RJ type;
msg RJs : msg RJs type;
msg ER : msg ER type;
ptr CR : TPDU CR type;          (* various kinds of ptrs *)
ptr DT : TPDU DT type;
ptr AK : TPDU AK type;
ptr DTs : TPDU DTs type;
ptr AKs : TPDU AKs type;
ptr DR : TPDU DR type;
ptr DC : TPDU DC type;
ptr RJ : TPDU RJ type;
ptr RJs : TPDU RJs type;
ptr ER : TPDU ER type;

tp msg : TPDU message type;

```

```

(***)
(***)      Common Procedures      (***)
(***)
(***)

```

```

procedure set_timer (FSM: TP4_machine_type;
                    time: integer;
                    kind: timer_type);      primitive;

```

```

    (* set timer *)

```

```

procedure set_retrans_timer;

```

```

    (* set re-trans timer *)

```

```

begin
set_timer (TP4M[l_ref], RETRANS_TIME, retrans);
end;

```

```

procedure set_ref_timer;

```

```

    (* set ref timer *)

```

```

begin
set_timer (TP4M[l_ref], REF_TIME, ref);
end;

```

```

procedure set_window_timer;

```

```

    (* set window timer *)

```

```

begin
set_timer (TP4M[l_ref], WINDOW_TIME, window);
end;

```

```

procedure set_inact_timer;

```

```

    (* set inact timer *)

```

```

begin
set_timer (TP4M[l_ref], INACT_TIME, inact);
end;

```

```
procedure stop_timer (FSM: TP4_machine_type;  
                      kind: timer_type);      primitive;
```

```
    (* stop timer *)
```

```
procedure stop_retrans_timer;
```

```
    (* stop retrans timer *)
```

```
begin  
    stop_timer (TP4M[l_ref], retrans);  
end;
```

```
procedure stop_window_timer;
```

```
    (* stop window timer *)
```

```
begin  
    stop_timer (TP4M[l_ref], window);  
end;
```

```
procedure stop_inact_timer;
```

```
    (* stop inact timer *)
```

```
begin  
    stop_timer (TP4M[l_ref], inact);  
end;
```

```
function timer (kind: timer_type): logical;      primitive;
```

```
    (* called at the timer interrupt *)
```

```
function set_credit: integer;  primitive;
```

```
    (* set credit for local TP4M for receiving.  It is used to  
       get the window width for the flow control.  The  
       function can be implemented by estimating the available  
       storage space in memory, dividing them between the  
       modules in the system, and between the active sessions  
       in the module. *)
```



```

function acceptable_param: logical;          primitive;

    (* check to see if the connection parameters
       are acceptable *)

function TP4_code (mes: IP_TP_message_type) : TPDU_code_type;

    (* check the TPDU_code of message from IP *)

    begin
    cur_mes := mes;
    cur_tpdu := cur_mes.data;
    cur_tpdu_code := cur_tpdu[2] / 16;          (* 4 bits at left *)
    TP4_code := cur_tpdu_code;
    end;

function TP_code (mes: TPDU_message_type) : TPDU_code_type;

    (* check the TPDU_code of message from TP-GW *)

    begin
    tp_mes := mes;
    cur_tpdu_code := tp_mes.tpdu_code;          (* 4 bits at right *)
    TP_code := cur_tpdu_code;
    end;

function tpdu_fixed : integer;

    (* get the pointer to the variable part in cur_tpdu *)

    var
    i,l: integer;

    begin
    l := cur_tpdu[1];          (* get Length Indicator *)
    case cur_tpdu_code of
        CRCODE,CCCODE,DRCODE:
            i := CR_VAR;          (* point to variable part *)
        DCCODE:
            i := DC_VAR;
        DTCODE,AKCODE,EDCODE,EACODE,ERCODE:
            begin
                i := DT_VAR;
                if (ex_flag) then
                    i := i+3;
                end;
            end;
    end; (* case *)
    tpdu_fixed := i;
    end;

```

```

procedure tpdu_checksum (var mes: IP_TP_message_type);
    (* complete the TPDU with checksum, etc. *)
var
    i,j,k,l: integer;
begin
    i := tpdu_fixed();          (* length of fixed part *)
    l := cur_tpdu[l]-i+1;       (* No. of bytes left, LI
                                exclude itself *)
    j := 0;
    i := i+1;                   (* point to variable part *)
    while ((l>0) and (j=0)) do
        begin
            if (cur_tpdu[i]=CHKSUMCODE) then
                j := i+2;        (* get pointer to checksum *)
            else
                begin
                    k := cur_tpdu[i+1]; (* get the length of field *)
                    l := l-k-2;
                    i := i+k+2;
                end;
            end;
        if (j>0) then
            mes.data := set_checksum(cur_tpdu, cur_tpdu.length, j);
        end;
    end;
end;

```

```

procedure accept_TPDU (mes: IP_TP_message_type);

  (* accept the control info in the TPDU from ISO-TP4 *)

begin
  cur_mes := mes;
  cur_tpdu := cur_mes.data;
  cur_tpdu_code := cur_tpdu[2] / 16;      (* 4 bits at left *)

  sub_state := true;                     (* true for OK *)
  if (r_ref=0) then
    r_ref := cur_tpdu.src_ref;           (* fill in remote ref *)
  else if (r_ref<>cur_tpdu.src_ref) then
    sub_state := false;

  if (s_ip_addr=0) then
    s_ip_addr := cur_tpdu.s_IP_addr;     (* fill in source IP *)
  else if (s_ip_addr<>cur_tpdu.s_IP_addr) then
    sub_state := false;

  if (d_ip_addr=0) then
    d_ip_addr := cur_tpdu.d_IP_addr;     (* fill in destin IP *)
  else if (d_ip_addr<>cur_tpdu.d_IP_addr) then
    sub_state := false;

  case cur_tpdu_code of
    CRCODE, CCCODE :
      begin
        ptr_CR := ^cur_tpdu;
        class := ptr_CR.class / 16;      (* left 4 bit for class *)
        if (ptr_CR.class and 2) then
          ex_flag := true;
        else
          ex_flag := false;
        if (cur_tpdu_code=CRCODE) then
          g_module := cur_mes.module/16;
        end;
      DRCODE :
        begin
          ptr_DR := ^cur_tpdu;
          reason := ptr_DR.reason;
        end;
      DTCODE, EDCODE :
        if (ex_flag=false) then          (* normal *)
          begin
            ptr_DT := ^cur_tpdu;
            seq := get_word (ptr_DT.seq_no, 1);
          end;
        else                             (* extended *)
          begin
            ptr_DTe := ^cur_tpdu;
            seq := ptr_DTe.seq_no;
          end;
      AKCODE, EACODE :

```

```

-      if (ex_flag=flase) then                      (* normal *)
-          begin
-              ptr_AK := ^cur_tpdu;
-              seq := get_word (ptr_AK.seq_no,1);
-              end;
-          else                                      (* extended *)
-              begin
-                  ptr_AKe := ^cur_tpdu;
-                  seq := ptr_AKe.seq_no;
-                  end;
-      RJCODE :
-          if (ex_flag=flase) then                  (* normal *)
-              begin
-                  ptr_RJ := ^cur_tpdu;
-                  seq := get_word (ptr_RJ.seq_no, 1);
-                  end;
-              else                                  (* extended *)
-                  begin
-                      ptr_RJe := ^cur_tpdu;
-                      seq := ptr_RJe.seq_no;
-                      end;
-      ERCODE :
-          begin
-              ptr_ER := ^cur_tpdu;
-              cause := ptr_ER.cause;
-              end;
-      default :                                    (* DC *)
-          null;
-  end;

-  case cur_tpdu_code of                            (* pick up credit *)
-      CRCODE,CCCODE :
-          cdt := ptr_CR.tpdu_code mod 16;
-      AKCODE :
-          if (ex_flag=flase) then                  (* normal *)
-              cdt := ptr_AK.tpdu_code mod 16;
-          else                                      (* extended *)
-              cdt := ptr_AKe.cdt;
-      RJCODE :
-          if (ex_flag=flase) then                  (* normal *)
-              cdt := ptr_RJ.tpdu_code mod 16;
-          else                                      (* extended *)
-              cdt := ptr_RJe.cdt;
-      default :
-          null;
-  end; (* case *)
-  end;

```

```

procedure accept_TP4_param;

  (* accept the control parameters in the TPDU from ISO-TP4 *)

var
  n: word_type;
  sn: short_word;
  i,j,k,l: integer;
  var_ptr: ^TP_var_part_type;

begin
  i := tpd_u_fixed();          (* ptr to variable parts *)
  var_ptr := ^cur_tpd_u[i+1];
  l := cur_tpd_u[l]-i+1;       (* length of variable part *)
  while (l>0) do
    begin
      k := var_ptr.length;

      case var_ptr.param_code of
        CALINGCODE :      (* 1100 0001: calling TSAP-ID *)
          if (k>2) then
            sub_state := false;
          else if (cur_tpd_u_code=CRCODE) then
            r_TSAP := get_sword (var_ptr.value, k);
          else if (cur_tpd_u_code<>CCCODE) then
            sub_state := false;
          else if (r_TSAP=0) then
            r_TSAP:=get_sword(var_ptr.value,k);
          else if (r_TSAP<>get_sword(var_ptr.value,k))) then
            sub_state := false;

        CALLED CODE :      (* 1100 0010: called TSAP-ID *)
          if (k>2) then
            sub_state := false;
          else if (cur_tpd_u_code=CRCODE) then
            l_TSAP := get_sword (var_ptr.value, k);
          else if (cur_tpd_u_code<>CCCODE) then
            sub_state := false;
          else if (l_TSAP=0) then
            l_TSAP:=get_sword(var_ptr.value,k);
          else if (l_TSAP<>get_sword(var_ptr.value,k))) then
            sub_state := false;

        PDUSIZCODE :      (* 1100 0000: TPDU size *)
          if (cur_tpd_u_code=CRCODE) then
            size := get_sword (var_ptr.value, k);
          else if (cur_tpd_u_code<>CCCODE) then
            sub_state := false;
          else
            begin
              sn := get_sword(var_ptr.value,k);
              if ((size=0) or (size>sn)) then
                size := sn;
            end;
      end;
    end;
  end;

```

```

VERSNOCODE :      (* 1100 0100: version number=1 *)
    vers := get_sword(var_ptr.value,k);

SECURICODE :      (* 1100 0101: protection *)
    prot := d_gets(var_ptr.value,1,k);

ADDLOPCODE :      (* 1100 0110: additional options *)
    begin
        sn := get_sword(var_ptr.value, k);
        if (sn and 2=0) then
            ch_flag := true;
        else
            ch_flag := false;
        if (sn and 1) then
            ed_flag := true;
        else
            ed_flag := false;
        end;

    ALTCLSCODE :      (* 1100 0111: alternative class *)
        begin
            if (class<>4) then
                for i := 1 to k do
                    if (var_ptr.value[i]=4) then
                        class := 4;
            if (class<>4) then
                sub_state := false;
            end;

    AKTIMECODE :      (* 1000 0101: acknowledge time *)
        ack_time := d_gets(var_ptr.value,1,k);

    THRUPTCODE :      (* 1000 1001: throughput *)
        throuput.max_AB := get_word(var_ptr.value[1],3);
        throuput.min_AB := get_word(var_ptr.value[4],3);
        throuput.max_BA := get_word(var_ptr.value[7],3);
        throuput.min_BA := get_word(var_ptr.value[10],3);
        if (k=24) then
            begin
                throuput.ave_AB := get_word(var_ptr.value[13],3);
                throuput.a_min_AB := get_word(var_ptr.value[16],3);
                throuput.ave_BA := get_word(var_ptr.value[19],3);
                throuput.a_min_BA := get_word(var_ptr.value[22],3);
            end;

    RESERRCODE :      (* 1000 0110: residual error rate *)
        res_error.target := get_word(var_ptr.value[1],1);
        res_error.min_acc := get_word(var_ptr.value[2],1);
        res_error.TSDU_size := get_word(var_ptr.value[3],1);

    PRIORTCODE :      (* 1000 0111: priority *)
        priority := get_word (var_ptr.value,k);

    TRNDELCODE :      (* 1000 1000: transit delay *)

```

```

        trans_delay.target_AB := get_word(var_ptr.value[1],2);
        trans_delay.max_AB := get_word(var_ptr.value[3],2);
        trans_delay.target_BA := get_word(var_ptr.value[5],2);
        trans_delay.max_BA := get_word(var_ptr.value[7],2);

        default :
            null;
        end; (* case *)

        var_ptr := ^var_ptr.value[k+1];
        l := l-k-2;
        end; (* while *)
    end;

```

```

procedure accept_TP_mes(mes: TPDU_message_type);

```

```

    (* accept the control info in the TPDU from TCP *)

```

```

var

```

```

    n: word_type;
    sn: short_word;
    i,j,k,l: integer;
    var_ptr: ^TP_var_part_type;

```

```

begin

```

```

    tp_mes := mes;

```

```

    cur_tpdu_code := tp_mes.tpdu_code; (* 4 bits at right *)

```

```

    if (g_ref=0) then

```

```

        g_ref := tp_mes.sr_ref; (* fill in remote ref *)

```

```

    sub_state := true; (* true for OK *)

```

```

case cur_tpdu_code of (* pick up special fields *)

```

```

    CRCODE,CCCODE :

```

```

        begin

```

```

            class := tp_mes.class;

```

```

            if (cur_tpdu_code=CRCODE) then

```

```

                begin

```

```

                    g_module := tp_mes.module mod 16;

```

```

                    d_ip_addr := tp_mes.d_IP_addr;

```

```

                    s_ip_addr := tp_mes.s_IP_addr;

```

```

                end;

```

```

            end;

```

```

        DRCODE :

```

```

            reason := tp_mes.reason;

```

```

        ERCODE :

```

```

            cause := tp_mes.reason;

```

```

        default :

```

```

            null;

```

```

        (* DC *)

```

```

    end;

```

```

    var_ptr := ^tp_mes.var_part;

```

```

    l := v_length; (* length of var. part *)

```

```

while (l>0) do
  begin
    k := var_ptr.length;
    case var_ptr.param_code of

      CALINGCODE :      (* 1100 0001: calling TSAP-ID *)
        if (cur_tpdu_code=CRCODE) then
          l_TSAP := get_sword (var_ptr.value, k);
        else if (cur_tpdu_code<>CCCODE) then
          sub_state := false;
        else if (l_TSAP=0) then
          l_TSAP:=get_sword(var_ptr.value,k);
        else if (l_TSAP<>get_sword(var_ptr.value,k)) then
          sub_state := false;

      CALLEDCODE :      (* 1100 0010: called TSAP-ID *)
        if (cur_tpdu_code=CRCODE) then
          r_TSAP := get_sword (var_ptr.value, k);
        else if (cur_tpdu_code<>CCCODE) then
          sub_state := false;
        else if (r_TSAP=0) then
          r_TSAP:=get_sword(var_ptr.value,k);
        else if (r_TSAP<>get_sword(var_ptr.value,k)) then
          sub_state := false;

      PDUSIZCODE :      (* 1100 0000: TPDU size *)
        if (cur_tpdu_code=CRCODE) then
          g_size := get_sword (var_ptr.value, k);
        else if (cur_tpdu_code<>CCCODE) then
          sub_state := false;
        else
          begin
            sn := get_sword(var_ptr.value,k);
            if ((g_size=0) or (g_size>sn)) then
              g_size := sn;
            end;

      VERSNOCODE :      (* 1100 0100: version number=1 *)
        g_vers := get_sword(var_ptr.value,k);

      SECURICODE :      (* 1100 0101: protection *)
        g_prot := d_gets(var_ptr.value,1,k);

      ALTCLSCODE :      (* 1100 0111: alternative class *)
        begin
          if (g_class<>4) then
            for i := 1 to k do
              if (var_ptr.value[i]=4) then
                g_class := var_ptr.value[i];
          if (g_class<>4) then
            sub_state := false;
          end;

      AKTIMECODE :      (* 1000 0101: acknowledge time *)
        g_ack_time := d_gets(var_ptr.value,1,k);
    end case;
  end;
end while;

```



```

THRUPCODE :      (* 1000 1001: throughput *)
begin
  g_throuput.max_AB := get_word(var_ptr.value[1],3);
  g_throuput.min_AB := get_word(var_ptr.value[4],3);
  g_throuput.max_BA := get_word(var_ptr.value[7],3);
  g_throuput.min_BA := get_word(var_ptr.value[10],3);
  if (k=24) then
    begin
      g_throuput.ave_AB := get_word(var_ptr.value[13],3);
      g_throuput.a_min_AB := get_word(var_ptr.value[16],3);
      g_throuput.ave_BA := get_word(var_ptr.value[19],3);
      g_throuput.a_min_BA := get_word(var_ptr.value[22],3);
    end;
  end;

RESERRCODE :      (* 1000 0110: residual error rate *)
begin
  g_res_error.target := get_word(var_ptr.value[1],1);
  g_res_error.min_acc := get_word(var_ptr.value[2],1);
  g_res_error.TSDU_size := get_word(var_ptr.value[3],1);
end;

PRIORTCODE :      (* 1000 0111: priority *)
  g_priority := get_word (var_ptr.value,k);

TRNDELCODE :      (* 1000 1000: transit delay *)
begin
  g_trans_delay.target_AB := get_word(var_ptr.value[1],2);
  g_trans_delay.max_AB := get_word(var_ptr.value[3],2);
  g_trans_delay.target_BA := get_word(var_ptr.value[5],2);
  g_trans_delay.max_BA := get_word(var_ptr.value[7],2);
end;

default:
  null;
end;

var_ptr := ^var_ptr.value[k+1];
l := l-k-2;
end;
end;

```

```

function acceptable_CR : boolean;

    (* check to see if CR/CC from ISO-TP4 is acceptable *)

var
    ok: boolean;

begin
    ok := sub_state;          (* set by accept_TPDU *)

    if((ok) and (class<>CLASS_4)) then
        ok := false;

    if (ok=true) then
        ok := acceptable_param();    (* check if parameters
                                       are acceptable *)

    acceptable_CR := ok;
end;


function encode_chksum : TP_var_part_type;

    (* make checksum entry *)

var
    var_ptr: TP_var_part_type;

begin
    var_ptr := d_create(4);
    var_ptr.param_code := CHKSUMCODE;
    var_ptr.length := 2;
    var_ptr.value := 0;
    encode_chksum := var_ptr;
end;


function encode_subseq : TP_var_part_type;

    (* make sub-sequence entry *)

var
    var_ptr: TP_var_part_type;

begin
    var_ptr := d_create(4);
    var_ptr.param_code := SUBSEQCODE;
    var_ptr.length := 2;
    var_ptr.value := r_sub_seq;
    encode_subseq := var_ptr;
end;

```

```

procedure build_DR (reason: reason_type;
                    mes: IP_TP_message_type);

(* build DR for ISO-TP4, in cases of:
   CLOSED * CC;
   WFCC * CC_not_acceptable;
   WBCL * CC;
   AKWAIT * ER;
   OPEN * ER;
   CLOSING * CR, CC, EA;
   REF_WAIT * CC *)

begin
mes_DR.module := (mes.module mod 16) * 16;
                (* shift l_module to d_module,
                  leave l_module blank *)

mes_DR.message := 0;
mes_DR.s_IP_addr := mes.d_IP_addr;
mes_DR.d_IP_addr := mes.s_IP_addr;

ptr_CR := ^mes.data;
mes_DR.tpdu.length := CR_VAR-1;      (* length of DR TPDU *)
mes_DR.tpdu.tpdu_code := DRCODE*16;
mes_DR.tpdu.dst_ref := ptr_CR.src_ref;
mes_DR.tpdu.src_ref := ptr_CR.dst_ref;
mes_DR.tpdu.reason := reason;
if (ch_flag) then
begin
mes_DR.tpdu.length := mes_DR.tpdu.length+4;
d_append(mes_DR.tpdu, encode_chksum);
set_checksum(mes_DR.tpdu, mes_DR.tpdu.length, CR_VAR+3);
end;
end;

```

```

procedure build_DC (mes: IP_TP_message_type);

(* build DC for ISO-TP4 in response to:
   CLOSED, WFCCout, AKWAIT, OPEN, REFWAIT * DR *)

begin
mes_DC.module := (mes.module mod 16) * 16
                + mes.module div 16;
                (* exchange l_module & d_module *)

mes_DC.message := 0;
mes_DC.s_IP_addr := mes.d_IP_addr;
mes_DC.d_IP_addr := mes.s_IP_addr;

ptr_DR := ^mes.data;

```

```

-   mes_DC.tpdu.length := DC_VAR-1;      (* length of DC TPDU *)
-   mes_DC.tpdu.tpdu_code := DCCODE*16;
-   mes_DC.tpdu.dst_ref := ptr_DR.src_ref;
-   mes_DC.tpdu.src_ref := ptr_DR.dst_ref;
-   if (ch_flag) then
-       begin
-           mes_DC.tpdu.length := mes_DC.tpdu.length+4;
-           d_append(mes_DC.tpdu, encode_chksum());
-           set_checksum(mes_DC.tpdu, mes_DC.tpdu.length, DC_VAR+3);
-       end;
-   end;

```

```

-   procedure build_CC (mes: IP_TP_message_type);

```

```

-       (* build CC for ISO-TP4 in response to: AKWAIT * CR *)

```

```

-       begin
-           mes_CC.module := (mes.module mod 16) * 16
-                           + mes.module div 16;
-                           (* exchange l_module & d_module *)
-           mes_CC.message := 0;
-           mes_CC.s_IP_addr := mes.d_IP_addr;
-           mes_CC.d_IP_addr := mes.s_IP_addr;
-
-           mes_CC.tpdu.length := CC_VAR-1;      (* length of CC TPDU *)
-           rcv_cdt := get_cdt;
-           mes_CC.tpdu.tpdu_code := CCCODE*16 + rcv_cdt;
-           mes_CC.tpdu.dst_ref := r_ref;
-           mes_CC.tpdu.src_ref := l_ref;
-           mes_CC.tpdu.class := class;
-           if (ch_flag) then
-               begin
-                   mes_CC.tpdu.length := mes_CC.tpdu.length+4;
-                   d_append(mes_CC.tpdu, encode_chksum());
-                   set_checksum(mes_CC.tpdu, mes_CC.tpdu.length, CR_VAR+3);
-               end;
-           end;

```

```

-   procedure make_DR (reason: reason_type);

```

```

-       (* make up DR for ISO-TP4, in cases of:
-         WFCC, WBCL, AKWAIT, OPEN * retrans_timer * count=max;
-         OPEN * inact_timer *)
-       begin
-           mes_DR.module := l_module * 16; (* shift l_module to d_module,
-                                           leave l_module blank *)
-           mes_DR.message := 0;
-           mes_DR.s_IP_addr := d_ip_addr;

```

```

mes_DR.d_IP_addr := s_ip_addr;

mes_DR.tpdu.length := CR_VAR-1;      (* length of DR TPDU *)
mes_DR.tpdu.tpdu_code := DRCODE*16;
mes_DR.tpdu.dst_ref := r_ref;
mes_DR.tpdu.src_ref := l_ref;
mes_DR.tpdu.reason := reason;
if (ch_flag) then
    begin
        mes_DR.tpdu.length := mes_DR.tpdu.length+4;
        d_append(mes_DR.tpdu, encode_chksum);
        set_checksum(mes_DR.tpdu, mes_DR.tpdu.length, CR_VAR+3);
    end;
end;

```

```

procedure append_flow;    primitive;

```

```

    (* append flow-control info onto the AK *)

```

```

procedure make_AK;

```

```

    (* make up AK for ISO-TP4, in cases of:

```

```

        OPEN * CC,
        OPEN * DT, ED,
        OPEN * timers *)

```

```

begin

```

```

    update_window();          (* update window control info *)

```

```

    if (ex_flag=false) then

```

```

        begin
            mes_AK.module := l_module * 16; (* shift l_mod to d_mod,
                                                leave l_mod blank *)

```

```

            mes_AK.message := 0;
            mes_AK.s_IP_addr := d_ip_addr;
            mes_AK.d_IP_addr := s_ip_addr;

```

```

            mes_AK.tpdu.length := DT_VAR-1;      (* length of AK TPDU *)

```

```

            mes_AK.tpdu.tpdu_code := AKCODE*16 + rcv_cdt;

```

```

            mes_AK.tpdu.dst_ref := r_ref;

```

```

            if (r_ack_seq<rcv_seq) then

```

```

                begin
                    r_ack_seq := rcv_seq;
                    r_sub_seq := 0;
                    mes_AK.tpdu.seq_no := r_ack_seq;
                end;

```

```

            else

```

```

                begin
                    mes_AK.tpdu.seq_no := r_ack_seq;

```

```

        r_sub_seq := r_sub_seq+1;
        mes_AK.tpdu.length := mes_AK.tpdu.length+4;
        d_append(mes_AK.tpdu, encode_subseq);
        end;
    if (ch_flag) then
        begin
            mes_AK.tpdu.length := mes_AK.tpdu.length+4;
            d_append(mes_AK.tpdu, encode_chksum);
            set_checksum(mes_AK.tpdu, mes_AK.tpdu.length, DT_VAR+3);
            end;
    end;
else (* ex_flag=true *)
    begin
        mes_AKe.module := l_module * 16; (* shift l_mod to d_mod,
                                           leave l_mod blank *)

        mes_AKe.message := 0;
        mes_AKe.s_IP_addr := d_ip_addr;
        mes_AKe.d_IP_addr := s_ip_addr;

        mes_AKe.tpdu.length := DTe_VAR-1; (* length of AKe TPDU *)
        mes_AKe.tpdu.tpdu_code := AKeCODE*16;
        mes_AKe.tpdu.cdt := rcv_cdt;
        mes_AKe.tpdu.dst_ref := r_ref;
        if (ch_flag) then
            begin
                mes_AKe.tpdu.length := mes_AKe.tpdu.length+4;
                d_append(mes_AKe.tpdu, encode_chksum);
                set_checksum(mes_AKe.tpdu, mes_AKe.tpdu.length,
                            DTe_VAR+3);
            end;
        if (r_ack_seq < rcv_seq) then
            begin
                r_ack_seq := rcv_seq;
                r_sub_seq := 0;
                mes_AKe.tpdu.seq_no := r_ack_seq;
            end;
        else
            begin
                mes_AKe.tpdu.seq_no := r_ack_seq;
                r_sub_seq := r_sub_seq+1;
                mes_AKe.tpdu.length := mes_AKe.tpdu.length+4;
                d_append(mes_AKe.tpdu, encode_subseq);
            end;
        end;
    end;
end;
end;

```

procedure make_EA;

(* make up EA for ISO-TP4, in cases of:

OPEN * CC,

OPEN * DT, ED,

OPEN * timers *)

begin

update_window(); (* update window control info *)

if (ex_flag=false) then

begin

mes_EA.module := l_module * 16; (* shift l_mod to d_mod,
leave l_mod blank *)

mes_EA.message := 0;

mes_EA.s_IP_addr := d_ip_addr;

mes_EA.d_IP_addr := s_ip_addr;

mes_EA.tpdu.length := DT_VAR-1; (* length of EA TPDU *)

mes_EA.tpdu.tpdu_code := EACODE*16 + rcv_cdt;

mes_EA.tpdu.dst_ref := r_ref;

if (r_ack_seq < rcv_seq) then

begin

r_ack_seq := rcv_seq;

r_sub_seq := 0;

mes_EA.tpdu.seq_no := r_ack_seq;

end;

else

begin

mes_EA.tpdu.seq_no := r_ack_seq;

r_sub_seq := r_sub_seq+1;

mes_EA.tpdu.length := mes_EA.tpdu.length+4;

d_append(mes_EA.tpdu, encode_subseq);

end;

if (ch_flag) then

begin

mes_EA.tpdu.length := mes_EA.tpdu.length+4;

d_append(mes_EA.tpdu, encode_chksum);

set_checksum(mes_EA.tpdu, mes_EA.tpdu.length, DT_VAR+3);

end;

end;

else (* ex_flag=true *)

begin

mes_EAe.module := l_module * 16; (* shift l_mod to d_mod,
leave l_mod blank *)

mes_EAe.message := 0;

mes_EAe.s_IP_addr := d_ip_addr;

mes_EAe.d_IP_addr := s_ip_addr;

mes_EAe.tpdu.length := DTe_VAR-1; (* length of EAe TPDU *)

mes_EAe.tpdu.tpdu_code := EAeCODE*16;

mes_EAe.tpdu.cdt := rcv_cdt;

mes_EAe.tpdu.dst_ref := r_ref;

```

if (ch_flag) then
begin
mes_EAe.tpdu.length := mes_EAe.tpdu.length+4;
d_append(mes_EAe.tpdu, encode_chksum);
set_checksum(mes_EAe.tpdu, mes_EAe.tpdu.length,
DTe_VAR+3);
end;
if (r_ack_seq<rcv_seq) then
begin
r_ack_seq := rcv_seq;
r_sub_seq := 0;
mes_EAe.tpdu.seq_no := r_ack_seq;
end;
else
begin
mes_EAe.tpdu.seq_no := r_ack_seq;
r_sub_seq := r_sub_seq+1;
mes_EAe.tpdu.length := mes_EAe.tpdu.length+4;
d_append(mes_EAe.tpdu, encode_subseq);
end;
end;
end;

```

```

procedure trans_CR;

```

```

(* translate CR of ISO-TP4 to GW format, in case of
CLOSED * CR *)

```

```

begin
tp_mes.module := mes_CR.module;
tp_mes.message := mes_CR.message;
tp_mes.s_IP_addr := mes_CR.s_IP_addr;
tp_mes.d_IP_addr := mes_CR.d_IP_addr;

tp_mes.tpdu_code := mes_CR.tpdu.tpdu_code/16;
tp_mes.dst_ref := g_ref;
tp_mes.src_ref := l_ref;
tp_mes.class := mes_CR.tpdu.class;
tp_mes.v_length := mes_CR.tpdu.length - tpdu_fixed() +1;
tp_mes.var_part := d_create(tp_mes.v_length);
d_puts (tp_mes.var_part, 1, mes_CR.tpdu.var_part);
tp_mes.d_length := d_length(mes_CR.tpdu.data);
tp_mes.data := d_create(tp_mes.d_length);
d_puts (tp_mes.data, 1, mes_CR.tpdu.data);
end;

```


procedure trans_CC;

(* translate CC of ISO-TP4 to GW format, in case of
WFCCiso * CC *)

begin

tp_mes.module := mes_CC.module;

tp_mes.message := mes_CC.message;

tp_mes.s_IP_addr := mes_CC.s_IP_addr;

tp_mes.d_IP_addr := mes_CC.d_IP_addr;

tp_mes.tpdu_code := mes_CC.tpdu.tpdu_code/16;

tp_mes.dst_ref := g_ref;

tp_mes.src_ref := l_ref;

tp_mes.class := mes_CC.tpdu.class;

tp_mes.v_length := mes_CC.tpdu.length - tpdu_fixed() +1;

tp_mes.var_part := d_create(tp_mes.v_length);

d_puts (tp_mes.var_part, 1, mes_CC.tpdu.var_part);

tp_mes.d_length := d_length(mes_CC.tpdu.data);

tp_mes.data := d_create(tp_mes.d_length);

d_puts (tp_mes.data, 1, mes_CC.tpdu.data);

end;

procedure trans_DR;

(* translate DR of ISO-TP4 to GW format, in case of
WFCCout, AKWAIT, OPEN * DR *)

begin

tp_mes.module := mes_DR.module;

tp_mes.message := mes_DR.message;

tp_mes.s_IP_addr := mes_DR.s_IP_addr;

tp_mes.d_IP_addr := mes_DR.d_IP_addr;

tp_mes.tpdu_code := mes_DR.tpdu.tpdu_code/16;

tp_mes.dst_ref := g_ref;

tp_mes.src_ref := l_ref;

tp_mes.reason := mes_DR.tpdu.reason;

tp_mes.v_length := mes_DR.tpdu.length - tpdu_fixed() +1;

tp_mes.var_part := d_create(tp_mes.v_length);

d_puts (tp_mes.var_part, 1, mes_DR.tpdu.var_part);

tp_mes.d_length := d_length(mes_DR.tpdu.data);

tp_mes.data := d_create(tp_mes.d_length);

d_puts (tp_mes.data, 1, mes_DR.tpdu.data);

end;

procedure trans_DT;

(* translate DT of ISO-TP4 to GW format, in case of
AKWAITiso, OPEN * DT *)

begin

tp_mes.dst_ref := g_ref;

tp_mes.src_ref := l_ref;

if (ex_flag=false) then

begin

tp_mes.module := mes_DT.module;

tp_mes.message := mes_DT.message;

tp_mes.s_IP_addr := mes_DT.s_IP_addr;

tp_mes.d_IP_addr := mes_DT.d_IP_addr;

tp_mes.tpdu_code := mes_DT.tpdu.tpdu_code/16;

tp_mes.class := mes_DT.tpdu.class;

tp_mes.v_length := mes_DT.tpdu.length - tpdu_fixed() +1;

tp_mes.var_part := d_create(tp_mes.v_length);

d_puts (tp_mes.var_part, 1, mes_DT.tpdu.var_part);

tp_mes.d_length := d_length(mes_DT.tpdu.data);

tp_mes.data := d_create(tp_mes.d_length);

d_puts (tp_mes.data, 1, mes_DT.tpdu.data);

end;

else

begin

tp_mes.module := mes_DTe.module;

tp_mes.message := mes_DTe.message;

tp_mes.s_IP_addr := mes_DTe.s_IP_addr;

tp_mes.d_IP_addr := mes_DTe.d_IP_addr;

tp_mes.tpdu_code := mes_DTe.tpdu.tpdu_code/16;

tp_mes.class := mes_DTe.tpdu.class;

tp_mes.v_length := mes_DTe.tpdu.length - tpdu_fixed() +1;

tp_mes.var_part := d_create(tp_mes.v_length);

d_puts (tp_mes.var_part, 1, mes_DTe.tpdu.var_part);

tp_mes.d_length := d_length(mes_DTe.tpdu.data);

tp_mes.data := d_create(tp_mes.d_length);

d_puts (tp_mes.data, 1, mes_DTe.tpdu.data);

end;

end;

procedure trans_ED;

(* translate ED of ISO-TP4 to GW format, in case of
AKWAITiso, OPEN * ED *)

begin

tp_mes.dst_ref := g_ref;

tp_mes.src_ref := l_ref;

if (ex_flag=false) then

begin

tp_mes.module := mes_ED.module;

```

    tp_mes.message := mes_ED.message;
    tp_mes.s_IP_addr := mes_ED.s_IP_addr;
    tp_mes.d_IP_addr := mes_ED.d_IP_addr;
    tp_mes.tpdu_code := mes_ED.tpdu.tpdu_code/16;
    tp_mes.class := mes_ED.tpdu.class;
    tp_mes.v_length := mes_ED.tpdu.length - tpdu_fixed() +1;
    tp_mes.var_part := d_create(tp_mes.v_length);
    d_puts (tp_mes.var_part, 1, mes_ED.tpdu.var_part);
    tp_mes.d_length := d_length(mes_ED.tpdu.data);
    tp_mes.data := d_create(tp_mes.d_length);
    d_puts (tp_mes.data, 1, mes_ED.tpdu.data);
end;
else
begin
    tp_mes.module := mes_EDe.module;
    tp_mes.message := mes_EDe.message;
    tp_mes.s_IP_addr := mes_EDe.s_IP_addr;
    tp_mes.d_IP_addr := mes_EDe.d_IP_addr;
    tp_mes.tpdu_code := mes_EDe.tpdu.tpdu_code/16;
    tp_mes.class := mes_EDe.tpdu.class;
    tp_mes.v_length := mes_EDe.tpdu.length - tpdu_fixed() +1;
    tp_mes.var_part := d_create(tp_mes.v_length);
    d_puts (tp_mes.var_part, 1, mes_EDe.tpdu.var_part);
    tp_mes.d_length := d_length(mes_EDe.tpdu.data);
    tp_mes.data := d_create(tp_mes.d_length);
    d_puts (tp_mes.data, 1, mes_EDe.tpdu.data);
end;
end;

```

```

. procedure make_DRg (reason);

```

```

    (* makeup DRg in GW format, in case of
       WFCCiso * CC not acceptable,
       WFCCiso, AKWAIT, OPEN * ER,
       retrans_timer & count=max,
       inact_timer *)

```

```

begin
    tp_mes.module := g_module * 16;
    tp_mes.message := 0;
    tp_mes.s_IP_addr := s_ip_addr;
    tp_mes.d_IP_addr := d_ip_addr;

    tp_mes.tpdu_code := DRCODE;
    tp_mes.dst_ref := g_ref;
    tp_mes.src_ref := l_ref;
    tp_mes.reason := reason;
    tp_mes.v_length := 0;
    tp_mes.d_length := 0;
end;

```

procedure trans_CRg;

(* translate CR of GW format to ISO-TP4 format, in case of
CLOSED * CRg *)

begin

mes_CR.module := tp_mes.module;

mes_CR.message := tp_mes.message;

mes_CR.s_IP_addr := tp_mes.s_IP_addr;

mes_CR.d_IP_addr := tp_mes.d_IP_addr;

mes_CR.tpdu.tpdu_code := tp_mes.tpdu_code * 16;

mes_CR.tpdu.dst_ref := r_ref;

mes_CR.tpdu.src_ref := l_ref;

mes_CR.tpdu.class := tp_mes.class;

tp_mes.var_part := d_create(tp_mes.v_length);

d_puts (mes_CR.tpdu.var_part, 1, tp_mes.var_part);

mes_CR.tpdu.data := d_create(tp_mes.d_length);

d_puts (mes_CR.tpdu.data, 1, tp_mes.data);

end;

procedure trans_CCg;

(* translate CC of GW format to ISO-TP4 format, in case of
WFCCout * CCg *)

begin

mes_CC.module := tp_mes.module;

mes_CC.message := tp_mes.message;

mes_CC.s_IP_addr := tp_mes.s_IP_addr;

mes_CC.d_IP_addr := tp_mes.d_IP_addr;

mes_CC.tpdu.tpdu_code := tp_mes.tpdu_code * 16;

mes_CC.tpdu.dst_ref := r_ref;

mes_CC.tpdu.src_ref := l_ref;

mes_CC.tpdu.class := tp_mes.class;

tp_mes.var_part := d_create(tp_mes.v_length);

d_puts (mes_CC.tpdu.var_part, 1, tp_mes.var_part);

mes_CC.tpdu.data := d_create(tp_mes.d_length);

d_puts (mes_CC.tpdu.data, 1, tp_mes.data);

end;

procedure trans_DRg;

(* translate DR of GW format to ISO-TP4 format, in case of
WFCCiso, WFCCout, AKWAITiso, OPEN * DRg *)

```
begin
mes_DR.module := tp_mes.module;
mes_DR.message := tp_mes.message;
mes_DR.s_IP_addr := tp_mes.s_IP_addr;
mes_DR.d_IP_addr := tp_mes.d_IP_addr;

mes_DR.tpdu.tpdu_code := tp_mes.tpdu_code * 16;
mes_DR.tpdu.dst_ref := r_ref;
mes_DR.tpdu.src_ref := l_ref;
mes_DR.tpdu.reason := tp_mes.reason;
tp_mes.var_part := d_create(tp_mes.v_length);
d_puts (mes_DR.tpdu.var_part, 1, tp_mes.var_part);
mes_DR.tpdu.data := d_create(tp_mes.d_length);
d_puts (mes_DR.tpdu.data, 1, tp_mes.data);
end;
```

procedure trans_DTg;

(* translate DT of GW format to ISO-TP4 format, in case of
AKWAITout, OPEN * DTg *)

```
begin
if (ex_flag=false) then
begin
mes_DT.module := tp_mes.module;
mes_DT.message := tp_mes.message;
mes_DT.s_IP_addr := tp_mes.s_IP_addr;
mes_DT.d_IP_addr := tp_mes.d_IP_addr;

mes_DT.tpdu.tpdu_code := tp_mes.tpdu_code * 16;
mes_DT.tpdu.dst_ref := r_ref;
mes_DT.tpdu.src_ref := l_ref;
mes_DT.tpdu.class := tp_mes.class;
tp_mes.var_part := d_create(tp_mes.v_length);
d_puts (mes_DT.tpdu.var_part, 1, tp_mes.var_part);
mes_DT.tpdu.data := d_create(tp_mes.d_length);
d_puts (mes_DT.tpdu.data, 1, tp_mes.data);
end;
else (* ex_flag=true *)
begin
mes_DTe.module := tp_mes.module;
mes_DTe.message := tp_mes.message;
mes_DTe.s_IP_addr := tp_mes.s_IP_addr;
mes_DTe.d_IP_addr := tp_mes.d_IP_addr;

mes_DTe.tpdu.tpdu_code := tp_mes.tpdu_code * 16;
```

```

mes_DTe.tpdu.dst_ref := r_ref;
mes_DTe.tpdu.src_ref := l_ref;
mes_DTe.tpdu.class := tp_mes.class;
tp_mes.var_part := d_create(tp_mes.v_length);
d_puts (mes_DTe.tpdu.var_part, 1, tp_mes.var_part);
mes_DTe.tpdu.data := d_create(tp_mes.d_length);
d_puts (mes_DTe.tpdu.data, 1, tp_mes.data);
end;
end;

```

```

procedure trans_EDg;

```

```

(* translate ED of GW format to ISO-TP4 format, in case of
   AKWAITout, OPEN * EDg *)

```

```

begin
if (ex_flag=false) then
begin
mes_ED.module := tp_mes.module;
mes_ED.message := tp_mes.message;
mes_ED.s_IP_addr := tp_mes.s_IP_addr;
mes_ED.d_IP_addr := tp_mes.d_IP_addr;

mes_ED.tpdu.tpdu_code := tp_mes.tpdu_code * 16;
mes_ED.tpdu.dst_ref := r_ref;
mes_ED.tpdu.src_ref := l_ref;
mes_ED.tpdu.class := tp_mes.class;
tp_mes.var_part := d_create(tp_mes.v_length);
d_puts (mes_ED.tpdu.var_part, 1, tp_mes.var_part);
mes_ED.tpdu.data := d_create(tp_mes.d_length);
d_puts (mes_ED.tpdu.data, 1, tp_mes.data);
end;
else (* ex_flag=true *)
begin
mes_EDe.module := tp_mes.module;
mes_EDe.message := tp_mes.message;
mes_EDe.s_IP_addr := tp_mes.s_IP_addr;
mes_EDe.d_IP_addr := tp_mes.d_IP_addr;

mes_EDe.tpdu.tpdu_code := tp_mes.tpdu_code * 16;
mes_EDe.tpdu.dst_ref := r_ref;
mes_EDe.tpdu.src_ref := l_ref;
mes_EDe.tpdu.class := tp_mes.class;
tp_mes.var_part := d_create(tp_mes.v_length);
d_puts (mes_EDe.tpdu.var_part, 1, tp_mes.var_part);
mes_EDe.tpdu.data := d_create(tp_mes.d_length);
d_puts (mes_EDe.tpdu.data, 1, tp_mes.data);
end;
end;

```

procedure check_queue; primitive;

(* Check all the TPDUs in the re-trans queue for re-transmission if necessary.

As specified in IS 8073, it is implementation-dependent to have timer control over the 1st TPDU only and re-transmit all TPDUs in the queue on time-out; or to have timer control over all the single TPDUs in the re-trans queue. *)

```

-      (***)
-      (***)      Initialization      (***)
-      (***)      (***)
-
- initialize
-
-     state := CLOSED;
-     proto_err := 0;
-
-     exp_flag := false;
-     exp_seq := 0;
-     exp_que.last := 0;
-
-
-
-      (***)      (***)
-      (***)      Transitions of TP4_machine      (***)
-      (***)      (***)
-
-      (***)  GROUP-1:  TPDU from ISO-TP4      (***)
-
-      (***)  State_transition from  CLOSED      (***)
-
- trans
-   when TP4M_I.TP4M_MESind (* CR from TP4 *)
-     provided ((TP4_code(message)=CRCODE)) and (l_ref=0))
-       from CLOSED to same
-
-     begin (* no conn available *)
-       build_DR (R_peer_congestion, message);
-       output TP4M_O.TP4M_MESreq(mes_DR);
-     end;

```



```

trans
  when TP4M_I.TP4M_MESind                                (* CR from TP4 *)
    provided ((TP4_code(message)=CRCODE)) and (l_ref<>0))
      from CLOSED

    begin
      accept_TPDU (message);                                (* take in the TPDU *)
      accept_TP4_param();
      if (acceptable_CR=false) then
        begin
          build_DR (R_CR_refused, message);
          output TP4M_O.TP4M_MESreq (mes_DR);
          next__state := same;
        end;
      else
        begin
          send_seq := 0;
          send_cdt := cdt;
          s_sub_seq := 0;
          s_ack_seq := 0;

          (* increase_count; *)
          (* set_retrans_timer; *)
          (* These two actions are specified in the original IS
              8073. But there might be some mistakes in it, because
              there is no specification in the CLASS-4 state table
              for the following state (WFTRESP) with the event of
              retrans_timer, and for the case of count exceeding the
              limit. It is assumed here that the CR_receiving side
              will passively wait for the TCONind from TP-4 user, or
              CRg from the TP-GW. If either the TCONind or CRg never
              comes, the calling TP-4 will finally timeout on the CR,
              and will send DR to terminate the connection
              establishment process. *)

          rcv_seq := 0;
          rcv_cdt := set_credit;
          r_sub_seq := 0;
          r_ack_seq := 0;
          trans_CR;
          output TP4I_O.TP4I_MESreq(tp_mes); (* send translated
                                              message to linker *)

          next_state := WFCCout;
        end;
      end;
    end;
end;

```

```

trans
  when TP4M_I.TP4M_MESind
    provided (TP4_code(message) = CCCODE)
      from CLOSED to SAME

    begin
      build_DR(R_ref_mismatched, message);
      output TP4M_O.TP4M_MESreq(mes_DR);
    end;

trans
  when TP4M_I.TP4M_MESind
    provided (TP4_code(message) = DRCODE)
      from CLOSED to SAME

    begin
      ptr_DR := ^message.data;
      if(ptr_DR.src_ref<>0) then
        build_DC(message);
        output TP4M_O.TP4M_MESreq(mes_DC);
      end;

trans
  when TP4M_I.TP4M_MESind
    provided ((TP4_code(message) = DTCODE) or
              (TP4_code(message) = AKCODE) or
              (TP4_code(message) = EDCODE) or
              (TP4_code(message) = EACODE) or
              (TP4_code(message) = DCCODE) or
              (TP4_code(message) = ERCODE) )
      from CLOSED to SAME

    begin
      proto_err := proto_err+1;
    end;

```

(*** State_transition from WFCCiso ***)

trans

when TP4M_I.TP4M_MESind
provided (TP4_code(message) = CCCODE)
from WFCCiso

var

retrans_ptr := ^retrans_type;

begin

stop_retrans_timer; (* for CR *)
accept_TPDU (message); (* take in the TPDU *)

accept_TP4_param();

if (acceptable_CR()) then

begin

send_seq := 0;
send_cdt := cdt;
s_sub_seq := 0;
s_ack_seq := 0;

re_trans.total := re_trans.total-1; (* remove CR from
retrans_queue *)

set_window_timer;

set_inact_timer;

trans_CC;

output TP4I_O.TP4I_MESreq(tp_mes); (* send translated
message to linker *)

next_state := AKWAITout;

end;

else (* CC not acceptable *)

begin

build_DR(R_negotiation_failed, message);

output TP4M_O.TP4M_MESreq(mes_DR);

retrans_ptr := re_trans.buf[1]; (* replace CR with DR *)

retrans_ptr.data := mes_DR;

retrans_ptr.count := 1;

retrans_ptr.timer := RETRANS_TIME;

set_retrans_timer;

make_DRg;

output TP4I_O.TP4I_MESreq(tp_mes); (* send TDISind *)

next_state := CLOSING;

end;

end;

```

trans
  when TP4M_I.TP4M_MESind
    provided (TP4_code(message) = DRCODE)
      from WFCCiso to REFWAIT

    begin
      accept_TPDU (message);           (* take in the TPDU *)
      accept_TP4_param();              (* but DC is not needed *)
      set_ref_timer;
      trans_DR;
      output TP4I_O.TP4I_MESreq(tp_mes); (* send TDISind to linker *)
    end;

```

```

trans
  when TP4M_I.TP4M_MESind
    provided (TP4_code(message) = ERCODE)
      from WFCCiso to REFWAIT

    begin
      accept_TPDU (message);           (* take in the TPDU *)
      accept_TP4_param();
      set_ref_timer;
      make_DRg;
      output TP4I_O.TP4I_MESreq(tp_mes); (* send TDISind to linker *)
    end;

```

(*** State_transition from WBCL ***)

```
trans
  when TP4M_I.TP4M_MESind
    provided (TP4_code(message) = CCCODE)
      from WBCL to CLOSING

    var
      retrans_ptr : retrans_type;

    begin
      stop_retrans_timer;
      accept_TPDU (message);          (* take in the TPDU *)
      accept_TP4_param();
      build_DR(R_negotiation_failed, message);
      output TP4M_O.TP4M_MESreq(mes_DR);
      retrans_ptr := re_trans.buf[1];
      retrans_ptr.data := mes_DR;    (* replace CR *)
      retrans_ptr.count := 1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
    end;
```

```
trans
  when TP4M_I.TP4M_MESind
    provided ((TP4_code(message) = DRCODE) or
              (TP4_code(message) = ERCODE) )
      from WBCL to REFWAIT

    begin
      set_ref_timer;
    end;
```

(*** State_transition from WFCCout ***)

trans

when TP4M_I.TP4M_MESind
provided (TP4_code(message) = CRCODE)
from WFCCout to SAME

begin
null; (* waiting for TCONresp *)
end;

trans

when TP4M_I.TP4M_MESind
provided (TP4_code(message) = DRCODE)
from WFCCout to CLOSED

begin
accept_TPDU (message); (* take in the TPDU *)
accept_TP4_param();
build_DC(message);
output TP4M_O.TP4M_MESreq(mes_DC);
trans_DR;
output TP4I_O.TP4I_MESreq(tp_mes); (* send TDISind to linker *)
flag_kill_me := now; (* terminate the TPM *)
end;

(*** State_transition from AKWAIT ***)

```
trans
  when TP4M_I.TP4M_MESind
    provided (TP4_code(message) = CRCODE)
      from AKWAIT to SAME

    var
      retrans_ptr: retrans_type;

    begin
      stop_retrans_timer;
      retrans_ptr := re_trans.buf[1];
      output TP4M_O.TP4M_MESreq(retrans_ptr.data); (* retrans CC *)
      retrans_ptr.count := 1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
    end;
```

```
trans
  when TP4M_I.TP4M_MESind
    provided (TP4_code(message) = ERCODE)
      from AKWAIT to CLOSING

    var
      retrans_ptr: retrans_type;

    begin
      stop_retrans_timer;
      accept_TPDU (message); (* take in the TPDU *)
      accept_TP4_param();
      retrans_ptr := re_trans.buf[1];
      build_DR(R_protocol_error, message);
      output TP4M_O.TP4M_MESreq(mes_DR);
      retrans_ptr.data := mes_DR; (* replace CC with DR *)
      retrans_ptr.count := 1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
      make_DRg;
      output TP4I_O.TP4I_MESreq(tp_mes); (* send TDISind *)
    end;
```

```

trans
  when TP4M_I.TP4M_MESind
    provided (TP4_code(message) = DRCODE)
      from AKWAIT to REFWAIT

    begin
      accept_TPDU (message);          (* take in the TPDU *)
      accept_TP4_param();
      build_DC(message);
      output_TP4M_O.TP4M_MESreq(mes_DC);
      set_ref_timer;
      trans_DR;
      output_TP4I_O.TP4I_MESreq(tp_mes); (* send TDISind *)
    end;

```



```

(***) State_transition from AKWAITiso (***)

trans
when TP4M_I.TP4M_MESind
  provided (TP4_code(message) = DTCODE)
  from AKWAITiso to OPEN

var
  out_flag: logical;

begin
  stop_retrans_timer;          (* no more re-trans CC *)
  re_trans.last := 0;          (* clear re-trans queue *)

  accept_TPDU (message);        (* take in the TPDU *)
  accept_TP4_param();
  out_flag := false;
  if ((TP4_code(message)=DTCODE) and (acceptable_DT=true)) then
    begin
      trans_DT;
      out_flag := true;
    end;
  else if ((TP4_code(message)=EDCODE) and (acceptable_ED=true))
  then
    begin
      trans_ED;
      out_flag := true;
    end;
  else if ((TP4_code(message)=AKCODE) and (acceptable_AK=true))
  then
    begin
      trans_AK;
      out_flag := true;
    end;
  if (out_flag=true) then
    output TP4I_O.TP4I_MESreq(tp_mes);
  set_inact_timer;
  set_inact_ack_timer;          (* for sending AK at suitable
                                interval in absence of
                                DT or ED *)

end;

```

(*** State_transition from OPEN ***)

trans

when TP4M_I.TP4M_MESind
provided (TP4_code(message) = CRCODE)
from OPEN to SAME

begin
stop_inact_timer;
set_inact_timer;
end;

trans

when TP4M_I.TP4M_MESind
provided (TP4_code(message) = CCCODE)
from OPEN to SAME

begin (* duplicated CC *)
stop_inact_timer;
make_AK;
output TP4M_O.TP4M_MESreq (mes_AK); (* repeat AK *)
set_inact_timer;
end;

trans

when TP4M_I.TP4M_MESind
provided (TP4_code(message) = ERCODE)
from OPEN to CLOSING

var
retrans_ptr: retrans_type;

begin
stop_window_timer;
stop_inact_timer;
stop_retrans_timer;
accept_TPDU (message); (* take in the TPDU *)
accept_TP4_param();
build_DR(R_protocol_error, message);
output TP4M_O.TP4M_MESreq(mes_DR);
retrans_ptr := re_trans.buf[1];
retrans_ptr.data := mes_DR;
retrans_ptr.count := 1;
retrans_ptr.timer := RETRANS_TIME;
set_retrans_timer;
make_DRg;
output TP4I_O.TP4I_MESreq(tp_mes); (* send TDISind to linker *)
end;

```

trans
  when TP4M_I.TP4M_MESind
    provided (TP4_code(message) = DRCODE)
      from OPEN to REFWAIT

    var
      retrans_ptr: retrans_type;

    begin
      stop_retrans_timer;
      accept_TPDU (message);          (* take in the TPDU *)
      accept_TP4_param();
      build_DC(message);
      output TP4M_O.TP4M_MESreq(mes_DC);
      retrans_ptr := re_trans.buf[1];
      retrans_ptr.data := mes_DC;
      retrans_ptr.count := 1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
      trans_DR;
      output TP4I_O.TP4I_MESreq(tp_mes); (* send TDISind to linker *)
      set_ref_timer;
    end;

```

```

trans
  when TP4M_I.TP4M_MESind
    provided (TP4_code(message) = DTCODE)
      from OPEN to SAME

    begin
      stop_inact_timer;
      accept_TPDU (message);          (* take in the TPDU *)
      accept_TP4_param();

      if (seq = rcv_seq) then          (* DT in sequence *)
        begin
          trans_DT;
          output TP4I_O.TP4I_MESreq(tp_mes);
          set_data_ack_timer;          (* set timer to ack
                                         during A_1 *)
          rcv_seq := rcv_seq + 1;
          while ((re_order.last > 0) and (* check re-seq queue *)
            (rcv_seq = re_order.buf[1].seq)) do
            begin
              message := re_order.buf[1].data;
              trans_DT;
              output TP4I_O.TP4I_MESreq(tp_mes);
              rcv_seq := rcv_seq + 1;
            end;
          end;
        end;
      end;

```



```

(* else, automatic drop the AK *)
if (re_trans.last>0) then
    set_retrans_timer;
set_inact_timer;
end;

```

```

trans
when TP4M_I.TP4M_MESind
    provided (TP4_code(message) = EDCODE)
        from OPEN to SAME

    var
        out_flag: logical;

    begin
        stop_inact_timer;
        accept_TPDU (message);           (* take in the TPDU *)
        accept_TP4_param();
        trans_ED;
        output_TP4I_O.TP4I_MESreq(tp_mes);
        build_EA;
        output_TP4M_O.TP4M_MESreq(mes_EA);
        re_trans.last := re_trans.last + 1;
        retrans_ptr := re_trans.buf[re_trans.last];
        retrans_ptr.data := mes_EA;
        retrans_ptr.count := 0;
        retrans_ptr.timer := RETRANS_TIME;
        set_retrans_timer;
        set_inact_timer;
    end;

```

```

trans
when TP4M_I.TP4M_MESind
    provided (TP4_code(message) = EACODE)
        from OPEN to SAME

    begin
        stop_inact_timer;
        stop_retrans_timer;
        accept_TPDU (message);           (* take in the TPDU *)
        accept_TP4_param();

        if (seq >= exp_seq) then         (* EA in sequence *)
            begin
                exp_seq := 0;
                exp_flag := false;       (* OK for DT to go now *)
            end;
        end;
    end;

```


(*** State_transition from CLOSING ***)

trans

```
when TP4M_I.TP4M_MESind
  provided ( (TP4_code(message) = CRCODE) or
             (TP4_code(message) = CCCODE) or
             (TP4_code(message) = DTCODE) or
             (TP4_code(message) = AKCODE) or
             (TP4_code(message) = EDCODE) or
             (TP4_code(message) = EACODE) )
    from CLOSING to SAME
```

var

reason: reason_type;

begin

accept_TPDU (message); (* take in the TPDU *)

accept_TP4_param();

if (TP4_code(message)=CRCODE) then

reason := R_CR_refused;

else if (TP4_code(message) = CCCODE) then

reason := R_negotiation_failed;

else

reason := R_protocol_error;

build_DR(reason, message);

output TP4M_O.TP4M_MESreq(mes_DR);

end;

trans

when TP4M_I.TP4M_MESind

```
  provided ( (TP4_code(message) = DRCODE) or
             (TP4_code(message) = DCCODE) or
             (TP4_code(message) = ERCODE) )
```

from CLOSING to REFWAIT

begin

set_ref_timer;

end;

(*** State_transition from REFWAIT ***)

trans

when TP4M_I.TP4M_MESind
provided (TP4_code(message) = CCCODE)
from REFWAIT to SAME

begin
accept_TPDU (message); (* take in the TPDU *)
accept_TP4_param();
build_DR(R_protocol_error, message);
output TP4M_O.TP4M_MESreq(mes_DR);
end;

trans

when TP4M_I.TP4M_MESind
provided (TP4_code(message) = DRCODE)
from REFWAIT to SAME

begin
accept_TPDU (message); (* take in the TPDU *)
accept_TP4_param();
if (r_ref<>0) then
build_DC(message);
output TP4M_O.TP4M_MESreq(mes_DC);
end;

trans

when TP4M_I.TP4M_MESind
provided ((TP4_code(message) = DTCODE) or
(TP4_code(message) = AKCODE) or
(TP4_code(message) = EDCODE) or
(TP4_code(message) = EACODE) or
(TP4_code(message) = DCCODE) or
(TP4_code(message) = ERCODE))
from REFWAIT to SAME

begin
null; (* waiting for ref_timer to expire *)
end;

(*** GROUP-2: timer-related ***)

```
trans
  from WFCCiso
    provided (timer(retrans))

    var
      retrans_ptr: ^retrans_type;

    begin
      (* only CR in retrans queue *)
      retrans_ptr := re_trans.buf[1];
      if (retrans_ptr.count < RETRANS_MAX) then
        begin
          output TP4M_O.TP4M_MESreq(mes_CR); (* re-trans CR *)
          retrans_ptr.count := retrans_ptr.count+1;
          retrans_ptr.timer := RETRANS_TIME;
          set_retrans_timer;
          next_state := SAME;
        end;
      else begin
        (* count = max *)
        stop_window_timer;
        stop_inact_timer;
        if (local_choice=false) then
          begin
            make_DR(R_retrans_timer); (* unspecified ! *)
            output TP4M_O.TP4M_MESreq(mes_DR);
            retrans_ptr.data := mes_DR;
            retrans_ptr.count := 1;
            retrans_ptr.timer := RETRANS_TIME;
            set_retrans_timer;
            make_DRg(R_retrans_timer);
            output TP4I_O.TP4I_MESreq(tp_mes); (* send TDISind *)
            next_state := CLOSING;
          end;
        else
          (* local choice *)
          begin
            make_DRg(R_retrans_timer);
            output TP4I_O.TP4I_MESreq(tp_mes); (* send TDISind *)
            set_ref_timer;
            next_state := REFWAIT;
          end;
        end;
      end;
    end;
  end; (* else count=max *)
end;
```

```

trans
  provided (timer(retrans))
    from WBCL

    var
      retrans_ptr: retrans_type;

    begin
      retrans_ptr := re_trans.buf[1];          (* only CR in queue *)
      if (retrans_ptr.count < RETRANS_MAX) then
        begin
          output TP4M_O.TP4M_MESreq(mes_CR);    (* re-trans *)
          retrans_ptr.count := retrans_ptr.count+1;
          retrans_ptr.timer := RETRANS_TIME;
          set_retrans_timer;
          next_state := SAME;
        end;
      else                                     (* count = max *)
        begin
          stop_window_timer;
          stop_inact_timer;
          if (local_choice=false) then
            begin
              make_DR(R_retrans_timer);
              output TP4M_O.TP4M_MESreq(mes_DR);
              retrans_ptr.data := mes_DR;      (* replace CR *)
              retrans_ptr.count := 1;
              retrans_ptr.timer := RETRANS_TIME;
              set_retrans_timer;
              next_state := CLOSING;
            end;
          else                                (* not local choice *)
            begin
              set_ref_timer;
              next_state := REFWAIT;
            end;
          end;
        end;
      end;
    end;
  end;
end;

```

```

trans
  provided (timer(retrans))
    from AKWAIT

    var
      retrans_ptr: retrans_type;

    begin
      retrans_ptr := re_trans.buf[1];
      if(retrans_ptr.count < RETRANS_MAX) then
        begin
          output TP4M_O.TP4M_MESreq(mes_CC);    (* retrans CC *)
          retrans_ptr.count := retrans_ptr.count+1;
          retrans_ptr.timer := RETRANS_TIME;
          set_retrans_timer;
          next_state := SAME;
        end;
      else
        begin
          (* count = max *)
          stop_window_timer;
          stop_inact_timer;
          make_DR(R_retrans_timer);
          output TP4M_O.TP4M_MESreq(mes_DR);
          retrans_ptr.data := mes_DR;    (* replace CC with DR *)
          retrans_ptr.count := 1;
          retrans_ptr.timer := RETRANS_TIME;
          set_retrans_timer;
          make_DRg(R_retrans_timer);
          output TP4I_O.TP4I_MESreq(tp_mes);  (* send TDISind *)
          next_state := CLOSING;
        end;
      end;
    end;

```

```

trans
  from OPEN
    provided (timer(retrans))

    var
      retrans_ptr: retrans_type;

    begin
      retrans_ptr := re_trans.buf[1];
      if (retrans_ptr.count < RETRANS_MAX) then
        begin
          output TP4M_O.TP4M_MESreq(retrans_ptr.data);
          retrans_ptr.count := retrans_ptr.count+1;
          retrans_ptr.timer := RETRANS_TIME;
          set_retrans_timer;
          check_queue;
          next_state := SAME;
        end;
      end;
    end;

```

```

-         else begin                                     (* count=MAX *)
-             stop_window_timer;
-             stop_inact_timer;
-             re_trans.total := 1;                       (* remove all retrans *)
-             retrans_ptr := re_trans.buf[1];
-             make_DR(R_retrans_timer);
-             output TP4M_O.TP4M_MESreq(mes_DR);
-             retrans_ptr.data := mes_DR;
-             retrans_ptr.count := 1;
-             retrans_ptr.timer := RETRANS_TIME;
-             set_retrans_timer;
-             make_DRg(R_retrans_timer);
-             output TP4I_O.TP4I_MESreq(tp_mes); (* send TDISind *)
-             next_state := CLOSING;
-         end;

```

```

-
- trans
-     provided (timer(retrans))
-     from CLOSING
-
-     var
-         retrans_ptr: retrans_type;
-
-     begin
-         retrans_ptr := re_trans.buf[1];
-         if (retrans_ptr.count < RETRANS_MAX) then
-             begin
-                 output TP4M_O.TP4M_MESreq(mes_DR);
-                 retrans_ptr.count := retrans_ptr.count+1;
-                 retrans_ptr.timer := RETRANS_TIME;
-                 set_retrans_timer;
-                 next_state := SAME;
-                 end;
-             else                                     (* count = MAX *)
-                 begin
-                     set_ref_timer;
-                     next_state := REFWAIT;
-                     end;
-             end;
-         end;

```

```

trans
  provided (timer(window))
    from OPEN to SAME          (* need to update window info *)

    var
      retrans_ptr: retrans_type;

    begin
      rcv_cdt := set_credit;    (* get new credit *)
      make_AK;
      append_flow;              (* append flow-ctrl parameters *)
      output_TP4M_O.TP4M_MESreq(mes_AK);
      re_trans.last := re_trans.last + 1;
      retrans_ptr := re_trans.buf[re_trans.last];
      retrans_ptr.data := mes_AK;
      retrans_ptr.count := 0;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
      set_window_timer;
    end;

```

```

trans
  provided (timer(data_ack))
    from OPEN to SAME          (* timer for acknowledge of
                                receiving data *)

    begin
      r_ack_seq := rcv_seq;
      make_AK;
      output_TP4M_O.TP4M_MESreq(mes_AK);
    end;

```

```

trans
  provided (timer(inact_ack))
    from OPEN to SAME          (* no DT/ED sent in the interval;
                                sending AK to keep active *)

    begin
      make_AK;
      output_TP4M_O.TP4M_MESreq(mes_AK);
      set_inact_ack_timer;
    end;

```

```

trans
  provided (timer(inact))
    from OPEN to CLOSING

    var
      retrans_ptr: retrans_type;

    begin
      stop_window_timer;
      stop_retrans_timer;
      make_DR(R_inact_timer); (* not specified ! *)
      output TP4M_O.TP4M_MESreq(mes_DR);
      re_trans.total := 1; (* remove all retrans *)
      retrans_ptr := re_trans.buf[1];
      retrans_ptr.data := mes_DR;
      retrans_ptr.count := 1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
      make_DRg(R_inact_timer);
      output TP4I_O.TP4I_MESreq(tp_mes); (* send TDISind to linker *)
    end;

```

```

trans
  provided (timer(ref))
    from REFWAIT to CLOSED

    begin
      flag_kill_me := now
    end;

```

(*** GROUP-3: TPDU from TRANSPORT GATEWAY ***)

trans

when TP4I_I.TP4I_MES.ind (* CR from gateway *)
provided (TP_code(message) = CRCODE)
from CLOSED to WFCCiso

var

retrans_ptr: retrans_type;

begin

accept_TP_mes (message); (* take in the TP_mes *)
rcv_cdt := set_credit;
trans_CRg;
output TP4M_O.TP4M_MESreq(mes_CR);
re_trans.total := 1;
retrans_ptr := re_trans.buf[1];
retrans_ptr.data := mes_CR;
retrans_ptr.count := 1;
retrans_ptr.timer := RETRANS_TIME;
set_retrans_timer;
end;

trans

when TP4I_I.TP4I_MESind
provided (TP_code(message) = DRCODE)
from WFCCiso

var

retrans_ptr: retrans_type;

begin

accept_TP_mes (message); (* take in the TP_mes *)
if (local_choice) then
next_state := WBCL;
else (* not local choice *)
begin
stop_retrans_timer;
accept_TP_mes (message); (* take in the TP_mes *)
trans_DRg;
output TP4M_O.TP4M_MESreq(mes_DR);
re_trans.total := 1;
retrans_ptr := re_trans.buf[1];
retrans_ptr.data := mes_DR;
retrans_ptr.count := 1;
retrans_ptr.timer := RETRANS_TIME;
set_retrans_timer;
end;

end;

```

trans
  when TP4I_I.TP4I_MESind
    provided (TP_code(message) = CCCODE)
      from WFCCout to AKWAITiso

    var
      retrans_ptr: retrans_type;

    begin
      accept_TP_mes (message);          (* take in the TP_mes *)
      rcv_cdt := set_credit;
      trans_CCg;
      output TP4M_O.TP4M_MESreq(mes_CC);
      re_trans.total := 1;
      retrans_ptr := re_trans.buf[1];
      retrans_ptr.data := mes_CC;
      retrans_ptr.count := 1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
    end;

```

```

trans
  when TP4I_I.TP4I_MESind
    provided (TP_code(message) = DRCODE)
      from WFCCout to CLOSED

    begin
      accept_TP_mes (message);          (* take in the TP_mes *)
      trans_DRg;
      output TP4M_O.TP4M_MESreq(mes_DR);
      flag_kill_me := now;
    end;

```

```

trans
  when TP4I_I.TP4I_MESind
    provided (TP_code(message) = DRCODE)
      from AKWAITiso to CLOSING

    var
      retrans_ptr: retrans_type;

    begin
      stop_retrans_timer;
      accept_TP_mes (message);          (* take in the TP_mes *)
      trans_DRg;
      output TP4M_O.TP4M_MESreq(mes_DR);
    end;

```



```

retrans_ptr := re_trans.buf[1];
retrans_ptr.data := mes_DR;
retrans_ptr.count := retrans_ptr.count+1;
retrans_ptr.timer := RETRANS_TIME;
set_retrans_timer;
end;

```

trans

```

when TP4I_I.TP4I_MESind
  provided (TP_code(message) = DTCODE)
    from AKWAIT to OPEN

  begin
    stop_inact_ack_timer;
    accept_TP_mes (message);          (* take in the TP_mes *)
    trans_DTg;
    output TP4M_O.TP4M_MESreq(mes_DT); (* send DT to TP4 Net *)
    retrans_ptr := re_trans.buf[1];
    retrans_ptr.data := mes_DT;
    retrans_ptr.count := retrans_ptr.count+1;
    retrans_ptr.timer := RETRANS_TIME;
    set_retrans_timer;
    set_window_timer;
    set_inact_timer;
    set_inact_ack_timer;
  end;

```

trans

```

when TP4I_I.TP4I_MESind
  provided (TP_code(message) = EDCODE)
    from AKWAIT to OPEN

  begin
    stop_inact_ack_timer;
    exp_flag := true;                (* to block future DTs *)
    accept_TP_mes (message);          (* take in the TP_mes *)
    trans_EDg;
    output TP4M_O.TP4M_MESreq(mes_ED); (* send ED to TP4 Net *)
    retrans_ptr := re_trans.buf[1];
    retrans_ptr.data := mes_ED;
    retrans_ptr.count := retrans_ptr.count+1;
    retrans_ptr.timer := RETRANS_TIME;
    set_retrans_timer;
    set_window_timer;
    set_inact_timer;
    set_inact_ack_timer;
  end;

```

```

trans
  when TP4I_I.TP4I_MESind
    provided (TP_code(message) = DRCODE)
      from OPEN to CLOSING

    var
      retrans_ptr: retrans_type;

    begin
      stop_window_timer;
      stop_inact_timer;
      stop_retrans_timer;
      accept_TP_mes (message);          (* take in the TP_mes *)
      trans_DRg;
      output TP4M_O.TP4M_MESreq(mes_DR);
      retrans_ptr := re_trans.buf[1];
      retrans_ptr.data := mes_DR;
      retrans_ptr.count := retrans_ptr.count+1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
      end;

trans
  when TP4I_I.TP4I_MESind
    provided (TP_code(message) = DTCODE)
      from OPEN to SAME

    begin
      stop_window_timer;
      stop_inact_timer;
      if (exp_flag=false) then
        begin
          accept_TP_mes (message);          (* take in the TP_mes *)
          trans_DTg;
          output TP4M_O.TP4M_MESreq(mes_DT);
          retrans_ptr := re_trans.buf[re_trans.last];
          retrans_ptr.data := mes_DT;
          retrans_ptr.count := retrans_ptr.count+1;
          retrans_ptr.timer := RETRANS_TIME;
          re_trans.last := re_trans.last + 1;
          set_retrans_timer;
          end;
        else
          (* blocked due to ED *)
          begin
            exp_que.last := exp_que.last + 1;
            exp_que.buf[exp_que.last] := message;
            end;
          set_window_timer;
          set_inact_timer;
          end;

```

```

trans
  when TP4I_I.TP4I_MESind
    provided (TP_code(message) = EDCODE)
      from OPEN to SAME

      begin
        stop_window_timer;
        stop_inact_timer;
        exp_flag := true;
        accept_TP_mes (message);
        trans_EDg;
        output TP4M_O.TP4M_MESreq(mes_ED);
        retrans_ptr := re_trans.buf[re_trans.last];
        retrans_ptr.data := mes_ED;
        retrans_ptr.count := retrans_ptr.count+1;
        retrans_ptr.timer := RETRANS_TIME;
        re_trans.last := re_trans.last + 1;
        set_retrans_timer;
        set_window_timer;
        set_inact_timer;
      end;

```

APPENDIX A.3.2 DDN_TCP SUBMODULE

```
(***)
(***)      DDN TCP Submodule Specification      (***)
(***)
```

body DDN_TCP_entity_body for DDN_TCP_entity_type;

type

```
TCP_HDR_type = record
    src_port  : short_word;      (* source port *)
    dst_port  : short_word;      (* destin port *)
    seq_num   : word_type;       (* sequence num *)
    ack_num   : word_type;       (* ack num *)
    offset    : octet;           (* header length *)
    flags     : octet;           (* TCP code *)
    window    : short_word;      (* window size *)
    checksum   : short_word;
    urg_ptr   : short_word;      (* urgent pointer *)
    options   : data_type;
    data      : data_type;       (* user data *)
end;
```

```
retrans_type = record
    timer : integer;      (* time left before retrans *)
    count : integer;      (* count of retrans *)
    data  : data_type;    (* PDU *)
end;
```

```
reorder_type = record
    seq : integer;      (* sequence number for re-order *)
    data : data_type;   (* PDU *)
end;
```

```

(***                                     ***)
(***      TCP Interface Interaction Point      ***)
(***                                     ***)

```

```

(* TP-4 State Machine Interaction Point *)

```

```

channel TCP_machine_primitives (user, provider);

```

```

by provider:
    TCPM_MESind (message : IP_TP_message_type);
                (* send TPDUs to TCP_machine *)

```

```

by user:
    TCPM_MESreq (message : IP_TP_message_type);
                (* TCP_machine sends TPDUs out *)

```

```

(* TP Transport Gateway Interaction Point (to linker module) *)

```

```

channel TCP_interface_primitives (user, provider);

```

```

by provider:
    TCPI_MESind (message : IP_TP_message_type);

```

```

by user:
    TCPI_MESreq (message : IP_TP_message_type);

```

```

(***                                     ***)
(***      TCP State Machine SubModule Specification      ***)
(***                                     ***)

```

```

module TCP_machine_type process

```

```

    (TCPM_I: TCP_machine_primitives (user);
     TCPM_O: TCP_machine_primitives (provider);
     TCPI_I: TCP_interface_primitives (user);
     TCPI_O: TCP_interface_primitives (provider);
    );

```

```

export

```

```

    state      : TCP_state_type; (* connection state *)
    l_module   : octet;          (* local module id *)
    g_module   : octet;          (* GW module id *)
    d_ip_addr  : word_type;      (* destination IP address *)
    s_ip_addr  : word_type;      (* source IP address *)
    l_ref      : short_word;     (* local reference *)
    r_ref      : short_word;     (* remote reference *)
    g_ref      : short_word;     (* gateway cross reference *)
end;

```

```

body TCP_machine_body for TCP_machine_type; external;

```

```

-      (***)
-      (***)   variables of the DDN_TCP_body   (***)
-      (***)   (***)

```

```

-  var

```

```

-      total_conn : integer;      (* total active transport conn *)
-      conn_flag   : array [1..MAX_CONN] of boolean;
-                               (* slot available flag *)
-      TCPM        : array [0..MAX_CONN] of TCP_machine_type;
-                               (* instance of TCP_machine *)
-
-      cur_conn: integer;          (* cur connection reference *)
-      direction : direction_type; (* cur mes flow direction *)
-      cur_mod_id : octet;         (* module Id *)
-      cur_mes_id : octet;         (* message Id *)
-      cur_mes : IP_TP_message_type; (* cur IP_TP message *)
-      cur_tpdu : TPDU_message_type; (* TPDU, used as pointer *)
-      cur_tcp : TCP_HDR_type;      (* TCP hdr, used as pointer *)
-      cur_s_IP : word_type;        (* source IP address *)
-      cur_d_IP : word_type;        (* destin IP address *)
-      cur_tp_code : TPDU_code_type; (* current TPDU code *)
-      src_port, dst_port: short_word;
-
-      total_mes : integer;      (* total messages going through *)
-      err_mes : integer;        (* messages with error conditions *)
-      fatal_err : integer;      (* fatal errors *)

```

```

(***                                     ***)
(***  Common Procedures of DDN_TCP_body  ***)
(***                                     ***)

```

```
function conn_alloc : integer;
```

```
    (* allocate a free slot of connection *)
```

```
var
```

```
    i,j : integer;
```

```
begin
```

```
    j := 0;
```

```
    if (total_conn < MAX_CONN) then
```

```
        for i := MAX_CONN to 1 do
```

```
            if (conn_flag[i] = false) then
```

```
                j := i;
```

```
    if (j > 0) then
```

```
        begin
```

```
            total_conn := total_conn+1;
```

```
            conn_flag[j] := true;
```

```
        end;
```

```
    conn_alloc := j;
```

```
end;
```

```

(* In the case of (total_conn=MAX_CONN), (conn_alloc=0) will be
returned. There exists a TCPM[0] to be used in this case to
respond to abnormal TPDUs. *)

```

```
procedure conn_free (j : integer); (* free the connection slot *)
```

```
begin
```

```
    if ((j>0) and (j<=MAX_CONN)) then
```

```
        if (conn_flag[j] = true) then
```

```
            begin
```

```
                conn_flag[j] := false;
```

```
                total_conn := total_conn-1;
```

```
            end;
```

```
end;
```

```
function TP_code (TPDU: TPDU_type): TPDU_code_type;
```

```
    (* check the TPDU_code of the TPDU *)
```

```
begin
```

```
    TP_code := TPDU[2];
```

```
    (* 4 bits at left *)
```

```
end;
```

```

function cur_TP_code (mes: IP_TP_message) : TPDU_code_type;

    (* check the TPDU_code of the 1st IP_TP message in queue *)

    begin
        cur_mes := mes;                                (* access NQ message *)
        cur_tpdu := cur_mes.data;                       (* point to TPDU *)
        cur_conn := cur_tpdu.dst_ref;                   (* TCP reference index *)
        cur_tp_code := TP_code(cur_tpdu);               (* get the TPDU code *)
        cur_TP_code := cur_tp_code;
    end;

```

```

function TCP_code (byte: octet): TPDU_code_type;

    (* check the TPDU_code of the TCP hdr *)

    begin
        case byte of
            0: TCP_code := DTCODE;                      (* *)
            1: TCP_code := DRCODE;                      (* FIN *)
            2: TCP_code := CRCODE;                      (* SYN *)
            4: TCP_code := RJCODE;                      (* RST *)
            8: TCP_code := DTCODE;                      (* PSH and data *)
            16: TCP_code := AKCODE;                     (* ACK *)
            18: TCP_code := CCCODE;                     (* SYN,ACK *)
            32: TCP_code := DTCODE;                     (* UGR and data *)
            40: TCP_code := DTCODE;                     (* URG,PSH, and data *)
            56: TCP_code := AKCODE;                     (* URG,PSH,ACK *)
        end;
    end;

```

```

function cur_TCP_code (mes: IP_TP_message) : TPDU_code_type;

    (* check the TCP code of the 1st IP_TP message in queue *)

    begin
        cur_mes := mes;
        cur_tcp := mes.data;                            (* point to TCP hdr *)
        cur_tp_code := TCP_code(cur_tcp.flags);          (* get the TPDU code *)
        if ((cur_tp_code=AKCODE) and d_length(cur_tcp.data)>0) then
            cur_tp_code = DTCODE;
        end if;
        cur_TCP_code := cur_tp_code;
    end;

```



```

function tcp_acceptable (mes: IP_TP_message_type) : boolean;

    (* check the TCP header to see if it is acceptable *)

var
    ok: boolean;
    i,j,k,l: integer;

begin
    ok := chk_checksum(mes.data, mes.data.offset*4);
    if (ok) then
        begin
            cur_TCP_code(mes);                (* get cur_tp_code, etc. *)

            cur_conn := 0;
            i := 0;
            while ((i<total_conn) and (cur_conn=0)) do
                begin
                    if((con_flag[i]=true) and
                       (TCPM[i].d_ip_addr=mes.d_IP_addr) and
                       (TCPM[i].s_ip_addr=mes.s_IP_addr) and
                       (TCPM[i].l_port=mes.data.dst_port) and
                       (TCPM[i].r_port=mes.data.src_port)) then
                        cur_conn := i;
                    else
                        i := i + 1;
                    end;
                end;

                if(cur_conn>0) then
                    begin
                        if (TCPM[cur_conn].g_module=0) then
                            TCPM[cur_conn].g_module = cur_mes.module/16;
                        else
                            if(TCPM[cur_conn].g_module<>cur_mes.module/16) then
                                ok := false;
                            if(TCPM[cur_conn].r_ref=0) then
                                TCPM[cur_conn].r_ref := cur_tpdu.src_ref;
                            else
                                if (cur_tpdu.src_ref<>TCPM[cur_conn].r_ref) then
                                    ok := false;                (* check the SRC_REF *)
                                end;
                            end;
                        end;
                    end;

                tcp_acceptable := ok;
            end;
        end;
    end;

```

```

function dup_CR (mes: IP_TP_message_type) : boolean;

    (* check the CR TPDU to see if it is duplicate *)

    var
        dup: boolean;
    begin
        cur_conn := 0;
        dup := false;
        i := 1;
        while ((i<=MAX_CONN) and (dup=false)) do
            begin
                if ((conn_flag[i]=true) and
                    (cur_mes.s_IP_addr=TCPM[i].s_ip_addr) and
                    (cur_mes.d_IP_addr=TCPM[i].d_ip_addr) and
                    (TCPM[i].l_port=cur_mes.data.dst_port) and
                    (TCPM[i].r_port=cur_mes.data.src_port)) then
                    begin
                        cur_conn := i;
                        dup := true;
                    end;

                    i := i+1;
                end;
            dup_CR := dup;
        end;

function dup_CRg (mes: TPDU_message_type) : boolean;

    (* check the CR TPDU from TP_GW to see if it is duplicate *)

    var
        dup: boolean;
        i: integer;
    begin
        cur_conn := 0;
        dup := false;
        i := 1;
        while((i<=MAX_CONN) and (dup=false)) do
            begin
                if ((conn_flag[i]=true) and
                    (mes.d_IP_addr=TCPM[i].s_ip_addr) and
                    (mes.s_IP_addr=TCPM[i].d_ip_addr) and
                    (TCPM[i].l_port=mes.data.dst_port) and
                    (TCPM[i].r_port=mes.data.src_port) and
                    (mes.src_ref=TCPM[i].g_ref)) then
                    begin
                        cur_conn := i;
                        dup := true;
                    end;

                    i := i+1;
                end;
            dup_CRg := dup;
        end;

```

```

(***                                     ***)
(***      Initialization of DDN_TCP_body      ***)
(***                                     ***)

```

initialize

```

total_mes := 0;          (* total messages *)
err_mes := 0;            (* error messages *)
fatal_err := 0;          (* fatal errors *)

total_conn := 0;         (* total transport connections *)
for i := 1 to MAX_CONN do
    conn_flag := false; (* the connection slot is free *)

init TCPM[0] with TCP_machine_interface_body();
                    (* virtual State_machine for
                    responding to error CR's *)

TCPM[0].l_ref := 0;
connect TCPM_I to TCPM[0].TCPM_I;
connect TCPI_I to TCPM[0].TCPI_I;
attach TCPM_O to TCPM[0].TCPM_O;
attach TCPI_O to TCPM[0].TCPI_O;

end;

```

```

(***                                     ***)
(***          State Transitions          ***)
(***                                     ***)

```

```

trans
  when NSi.IP_TP_MESind priority 0      (* receive from DDN-IP *)

```

```

    begin
      total_mes := total_mes+1;
      direction := in;

      if (tcp_acceptable(message)=false) then
        err_mes := err_mes+1;          (* TPDU not acceptable *)
      else if (cur_tp_code=CRCODE) then (* and cur_conn=0 *)
        begin                          (* Connection Request *)
          if (dup_CR(message)=false) then
            begin
              cur_conn := conn_alloc();
              if (cur_conn>0) then
                begin                  (* initialize TCP protocol
                                     machine *)
                  init TCPM[cur_conn] with
                    TCP_machine_interface_body();
                  with TCPM[cur_conn] do
                    begin
                      l_ref := cur_conn;
                      flag_kill_me := conn_in_progress;
                    end;
                    connect TCPM_I to TCPM[cur_conn].TCPM_I;
                    connect TCPI_I to TCPM[cur_conn].TCPI_I;
                    attach TCPM_O to TCPM[cur_conn].TCPM_O;
                    attach TCPI_O to TCPM[cur_conn].TCPI_O;
                    end; (* if conn *)
                  end; (* if dup_CR *)
                output TCPM[cur_conn].TCPM_I(message);
                (* pass TPDU for further check or response *)
              end; (* if CR *)
            else
              output TCPM[cur_conn].TCPM_I(message);
            end; (* trans *)
          end;

```

```

(* For duplicated CR, the state machine TCPM[cur_conn] will
   response to it with CC.

```

```

In case there is no local connection slot available,
cur_conn is reset to 0 by dup_CR(), or by conn_alloc(), the
CR will be passed to TCPM[0] which will in turn send a DR to
refuse the connection request. *)

```

```

trans
  when TGS.TP_MESreq priority 0      (* receive from TCP, begore
                                      feeding into TCP_machine *)

  begin
    total_mes := total_mes+1;
    direction := out;
    cur_mes := message;
    cur_tpdu := cur_mes.data;          (* point to TPDU *)
    cur_conn := cur_tpdu.src_ref;      (* TCP reference index *)
    cur_tp_code := TP_code(cur_tpdu);  (* get the TPDU code *)
    case cur_tp_code of
      CCCODE,DRCODE,DCCODE,DTCODE,
      AKCODE,ERCODE,RJCODE :
        output TCPM[cur_conn].TCPI_I(message);

      CRCODE :
        begin
          if (dup_CRg(message)=false) then
            begin
              cur_conn := conn_alloc();
              if (cur_conn>0) then
                begin      (* initialize a new TCP_machine *)
                  init TCPM[cur_conn] with
                    TCP_machine_interface_body();
                  with TCPM[cur_conn] do
                    begin
                      l_ref := cur_conn;
                      flag_kill_me := conn_in_progress;
                    end;
                    connect TCPM_I to TCPM[cur_conn].TCPM_I;
                    connect TCPI_I to TCPM[cur_conn].TCPI_I;
                    attach TCPM_O to TCPM[cur_conn].TCPM_O;
                    attach TCPI_O to TCPM[cur_conn].TCPI_O;
                  end; (* if conn *)
                end; (* if *)
              output TCPM[cur_conn].TCPI_I(message);
              (* pass TPDU for further checking *)
            end; (* case CR *)
          end; (* case *)
        end; (* trans *)

```

```

trans
  any TCPM[i]: TCP_machine_interface_type do
    provided (TCPM[i].flag_kill_me = now) priority 1

    begin
      disconnect TCPM[i].TCPM_I; (* disconnect port relations *)
      disconnect TCPM[i].TCPI_I;
      detach TCPM[i].TCPM_O;
      detach TCPM[i].TCPI_O;
      release TCPM[i]; (* terminate TCP_machine *)
      conn_free(i); (* free the slot for future use *)
    end;

end; (* of DDN_TCP_body *)

```

```

(***                                     ***)
(***   TCP_machine_interface_body   Specification   ***)
(***                                     ***)

```

body TCP_machine_interface_body for TCP_machine_interface_type;

type

```

TCP_state_type = (CLOSED, ESTAB, SYN_SENTddn,
                  SYN_SENTout, SYN_RCVDddn, SYN_RCVDout,
                  FIN_WAITddn, FIN_WAITout, TIME_WAIT);

```

```

OPTION_END = 0;
OPTION_NO = 1;
OPTION_SIZE = 2;

```

var

```

proto_err : integer;      (* fatal errors *)
l_port    : short_word;   (* local port id *)
r_port    : short_word;   (* remote port id *)
initiator : initiator_type; (* who initiate the conn *)
size      : octet;        (* max TPDU size *)
g_size    : octet;        (* GW max TPDU size *)
snd_nxt   : word_type;    (* sending sequence no *)
snd_wnd   : short_word;   (* sending credit *)
snd_ack   : word_type;    (* ack_ed sequence no *)
rcv_nxt   : word_type;    (* receiving sequence no *)
rcv_wnd   : short_word;   (* receiving credit *)
rcv_ack   : word_type;    (* ack_ed sequence no *)

re_trans  : queue_type of retrans_type; (* retransmission *)
re_order  : queue_type of reorder_type; (* re-order *)

cur_mes   : IP_TP_message_type; (* cur IP_TP message *)
cur_tpdu  : TPDU_type;          (* TPDU, used as pointer *)
cur_tcp   : TCP_HDR_type;       (* TCP hdr *)
cur_tp_code : TPDU_code_type;   (* current TPDU code *)
var_ptr   : ^TP_var_part_type;  (* ptr to variable part *)
sub_state : boolean;            (* associated flag *)
seq,ack   : word_type;
wnd       : short_word;

```

```

tp_mes : TPDU_message_type;

```

```

-      (***)
-      (***)      Common Procedures      (***)
-      (***)      (***)

-  procedure set_timer (FSM: TCP_machine_type;
-                      time: integer;
-                      kind: timer_type);      primitive;
-
-      (* set timer *)
-
-
-  procedure set_retrans_timer;
-
-      (* set re-trans timer *)
-
-      begin
-      set_timer (TCPM[l_ref], RETRANS_TIME, retrans);
-      end;
-
-
-  procedure set_ref_timer;
-
-      (* set ref timer *)
-
-      begin
-      set_timer (TCPM[l_ref], REF_TIME, ref);
-      end;
-
-
-  procedure set_window_timer;
-
-      (* set window timer *)
-
-      begin
-      set_timer (TCPM[l_ref], WINDOW_TIME, window);
-      end;
-
-
-  procedure set_inact_timer;
-
-      (* set inact timer *)
-
-      begin
-      set_timer (TCPM[l_ref], INACT_TIME, inact);
-      end;
-
-
-
-

```



```

procedure stop_timer (FSM: TCP_machine_type;
                      kind: timer_type);      primitive;

    (* stop timer *)

procedure stop_retrans_timer;

    (* stop retrans timer *)

begin
    stop_timer (TCPM[l_ref], retrans);
end;

procedure stop_window_timer;

    (* stop window timer *)

begin
    stop_timer (TCPM[l_ref], window);
end;

procedure stop_inact_timer;

    (* stop inact timer *)

begin
    stop_timer (TCPM[l_ref], inact);
end;

function timer (kind: timer_type): logical;      primitive;

    (* dst at the timer interrupt *)

function set_window: integer;  primitive;

    (* set window size for local TCPM receiving.  It is used to
       get the window width for the flow control.  The
       function can be implemented by estimating the available
       storage space in memory, dividing them between the
       modules in the system, and between the active sessions
       in the module. *)

```

```

function trans_d_port(addr: short_word) : short_word; primitive;
    (* translate DDN_TCP port address to GW_TP address *)

function trans_g_port(addr: short_word) : short_word; primitive;
    (* translate GW_TP address to DDN_TCP port address *)

function cur_TCP_code (mes: IP_TP_message_type) : TPDU_code_type;
    (* check the TPDU_code of message from IP *)
begin
    cur_mes := mes;
    cur_tcp := cur_mes.data;
    cur_tp_code := TCP_code(cur_tcp.flags);      (* 4 bits at left *)
    cur_TCP_code := cur_tp_code;
end;

function TP_code (mes: TPDU_message_type) : TPDU_code_type;
    (* check the TPDU_code of message from TP-GW *)
begin
    tp_mes := mes;
    cur_tp_code := tp_mes.tpdu_code;      (* 4 bits at right *)
    TP_code := cur_tp_code;
end;

procedure tcp_checksum (var mes: IP_TP_message_type);
    (* complete the TPDU with checksum, etc. *)
begin
    mes.data := set_checksum(cur_tcp, cur_tcp.offset*4, 17);
end;

```

```

procedure accept_TPDU (mes: IP_TP_message_type);

  (* accept the control info in the TPDU from DDN-TCP *)

  var
    sn: word_type;

  begin
    cur_mes := mes;
    cur_tpdu := cur_mes.data;
    cur_tpdu_code := cur_tpdu[2] / 16;      (* 4 bits at left *)

    sub_state := true;                      (* true for OK *)
    if (s_ip_addr=0) then
      s_ip_addr := cur_mes.s_IP_addr;      (* fill in source IP *)
    else if (s_ip_addr<>cur_mes.s_IP_addr) then
      sub_state := false;

    if (d_ip_addr=0) then
      d_ip_addr := cur_mes.d_IP_addr;      (* fill in destin IP *)
    else if (d_ip_addr<>cur_mes.d_IP_addr) then
      sub_state := false;

    if (l_port=0) then
      l_port := cur_tpdu.dst_port;
    else if (l_port<>cur_tpdu.dst_port) then
      sub_state := false;

    if (r_port=0) then
      r_port := cur_tpdu.src_port;
    else if (r_port<>cur_tpdu.src_port) then
      sub_state := false;

    seq := cur_tpdu.seq;
    ack := cur_tpdu.ack;
    wnd := cur_tpdu.wnd;

    sn := 0;
    i := 1;
    var_ptr := cur_tpdu.options;
    l := cur_tpdu.Offset*4-20;              (* length of options *)
    while (l>0) do
      begin
        case var_ptr[l] of
          OPTION_END :      (* 0000 0000: No more *)
            l := 0;
          OPTION_SIZE:      (* 0000 0002: Max PDU size *)
            begin
              sn := get_word (var_ptr, 3);
              l := l-3;
              i := i+3;
            end;
        end;
      end;
      l := l-1;
    end;
    default :                (* CHKSUMCODE, REASSIGN, etc *)

```

```

        null;
    end; (* case *)

    var_ptr := ^var_ptr[2];
    l := l-1;
end; (* while *)
end;

procedure accept_TP_mes(mes: TPDU_message_type);

(* accept the control info in the TPDU from TCP *)

var
n: word_type;
sn: short_word;
i,j,k,l: integer;
var_ptr: ^TP_var_part_type;

begin
tp_mes := mes;
cur_tp_code := tp_mes.tpdu_code; (* 4 bits at right *)
if (g_ref=0) then
    g_ref := tp_mes.src_ref;      (* fill in remote ref *)
sub_state := true;              (* true for OK *)

if (cur_tp_code=CRCODE) then
    begin
        g_module := tp_mes.module mod 16;
        d_ip_addr := tp_mes.d_IP_addr;
        s_ip_addr := tp_mes.s_IP_addr;
    end;

var_ptr := ^tp_mes.var_part;
l := v_length;                  (* length of var. part *)
while (l>0) do
    begin
        k := var_ptr.length;
        case var_ptr.param_code of

            CALINGCODE :       (* 1100 0001: src port-ID *)
                if (cur_tp_code=CRCODE) then
                    l_port := get_sword(var_ptr.value, k);
                else if (cur_tp_code<>CCCODE) then
                    sub_state := false;
                else if (l_port=0) then
                    l_port:=get_sword(var_ptr.value,k);
                else if (l_port<>get_sword(var_ptr.value,k)) then
                    sub_state := false;

            CALLED_CODE :     (* 1100 0010: dst port-ID *)
                if (cur_tp_code=CRCODE) then
                    r_port := get_sword(var_ptr.value, k);

```

```

else if (cur_tp_code<>CCCODE) then
    sub_state := false;
else if (r_port=0) then
    r_port:=get_sword(var_ptr.value,k);
else if (r_port<>get_sword(var_ptr.value,k)) then
    sub_state := false;

PDUSIZCODE :      (* 1100 0000: TPDU size *)
    if (cur_tp_code=CRCODE) then
        g_size := get_sword (var_ptr.value, k);
    else if (cur_tp_code<>CCCODE) then
        sub_state := false;
    else
        begin
            sn := get_sword(var_ptr.value,k);
            if ((g_size=0) or (g_size>sn)) then
                g_size := sn;
            end;

var_ptr := ^var_ptr.value[k+1];
l := l-k-2;
end;
end;

```

procedure build_TCP;

(* filling in the parts of TCP header, and GW message header *)

begin

cur_tcp.src_port := l_port;

cur_tcp.dst_port := r_port;

cur_tcp.seq_numt := snd_nxt;

cur_tcp.ack_numt := rcv_nxt;

cur_tcp.window := rcv_wnd;

tcp_checksum(cur_tcp);

cur_mes.module := l_module;

cur_mes.s_IP_addr := d_ip_addr;

cur_mes.d_IP_addr := s_ip_addr;

cur_mes.data := cur_tcp;

end;

procedure build_ER;

(* build ER for DDN-TCP, in cases of any protocol error *)

begin

cur_tcp.flags := RST;

cur_tcp.offset := 5;

build_TCP;

end;

procedure build_DC;

(* build DC for DDN-TCP in response to:
FIN-WAIT * FIN *)

begin

cur_tcp.flags := FIN+ACK;

cur_tcp.offset := 5;

build_TCP;

end;

```
procedure build_CC;
```

```
  (* build CC for DDN-TCP *)
```

```
begin
  cur_tcp.flags := SYN+ACK;
  cur_tcp.offset := 5;
  build_TCP;
end;
```

```
procedure build_AK;
```

```
  (* make up AK for DDN-TCP, in cases of:
     ESTAB * DT,
     ESTAB * timers *)
```

```
begin
  update_window();          (* update window control info *)
  cur_tcp.flags := cur_tcp.flags + ACK;
  cur_tcp.offset := 5;
  build_TCP;
end;
```

```
function opt_calling(port: short_word): data_type;
```

```
  (* make up calling TASP option *)
```

```
  var
```

```
    ptr: data_type;
```

```
begin
  ptr := d_create(4);
  ptr[1] := CALINGCODE;
  ptr[2] := 2;
  d_puts(ptr, 3, d_encode2(port));
  opt_calling := ptr;
end;
```

```
function opt_called(port: short_word): data_type;
```

```
    (* make up called TASP option *)
```

```
    var
```

```
        ptr: data_type;
```

```
    begin
```

```
        ptr := d_create(4);
```

```
        ptr[1] := CALLEDCODE;
```

```
        ptr[2] := 2;
```

```
        d_puts(ptr, 3, d_encode2(port));
```

```
        opt_called := ptr;
```

```
    end;
```

```
procedure trans_TCP;
```

```
    (* common operation to translate TCP TPDUs into TP GW format *)
```

```
    begin
```

```
        tp_mes.module := cur_mes.module;
```

```
        tp_mes.message := cur_mes.message;
```

```
        tp_mes.s_IP_addr := cur_mes.s_IP_addr;
```

```
        tp_mes.d_IP_addr := cur_mes.d_IP_addr;
```

```
        tp_mes.dst_ref := g_ref;
```

```
        tp_mes.src_ref := l_ref;
```

```
        tp_mes.class := 4;
```

```
        tp_mes.v_length := d_length(tp_mes.var_part);
```

```
        tp_mes.d_length := d_length(cur_tcp.data);
```

```
        tp_mes.data := d_create(tp_mes.d_length);
```

```
        d_puts (tp_mes.data, 1, cur_tcp.data);
```

```
    end;
```

```
procedure trans_CR;
```

```
    (* translate CR of DDN-TCP to GW format, in case of  
      CLOSED * CR *)
```

```
    begin
```

```
        tp_mes.code := CRCODE;
```

```
        tp_mes.var_part := opt_calling(trans_d_port(l_port));
```

```
        tp_mes.var_part := d_append(opt_called(trans_d_port(r_port)));
```

```
        trans_TCP;
```

```
    end;
```


procedure trans_CC;

(* translate CC of DDN-TCP to GW format, in case of
SYN_SENTddn * CC *)

begin
tp_mes.code := CCCODE;
tp_mes.var_part := opt_calling(trans_d_port(l_port));
tp_mes.var_part := d_append(opt_called(trans_d_port(r_port)));
trans_TCP;
end;

procedure trans_DR;

(* translate DR of DDN-TCP to GW format, in case of
ESTAB * FIN *)

begin
tp_mes.code := DRCODE;
tp_mes.var_part := opt_calling(trans_d_port(l_port));
tp_mes.var_part := d_append(opt_called(trans_d_port(r_port)));
trans_TCP;
end;

procedure trans_DT;

(* translate DT of DDN-TCP to GW format, in case of
SYN_RCVDddn, ESTAB * DT *)

begin
tp_mes.code := DTCODE;
tp_mes.var_part := opt_calling(trans_d_port(l_port));
tp_mes.var_part := d_append(opt_called(trans_d_port(r_port)));
trans_TCP;
end;

procedure trans_CRg;

(* translate CR of GW format to DDN-TCP format, in case of
CLOSED * CRg *)

begin
update_window(); (* update window control info *)
cur_tcp.flags := SYN;
cur_tcp.offset := 5;
build_TCP;
end;

```
procedure trans_CCg;
```

```
(* translate CC of GW format to DDN-TCP format, in case of
   SYN_SENTout * CCg *)
```

```
begin
update_window();           (* update window control info *)
cur_tcp.flags := SYN + ACK;
cur_tcp.offset := 5;
build_TCP;
end;
```

```
procedure trans_DRg;
```

```
(* translate DR of GW format to DDN-TCP format, in case of
  SYN_SENTddn, SYN_SENTout, SYN_RCVDddn, ESTAB * DRg *)
```

```
begin
cur_tcp.flags := FIN
cur_tcp.offset := 5;
build_TCP;
end;
```

```
procedure trans_DTg;
```

```
(* translate DT of GW format to DDN-TCP format, in case of
   ESTAB * DTg *)
```

```
begin
cur_tcp.flags := 0;
cur_tcp.offset := 5;
build_TCP;
end;
```

```
procedure check queue; primitive;
```

```
(* Check all the TPDUs in the re-trans queue for re-
   transmission if necessary. *)
```

```

(***                                     ***)
(***             Initialization          ***)
(***                                     ***)

```

initialize

```

state := CLOSED;
proto_err := 0;

```

```

(***                                     ***)
(***       Transitions of TCP_machine   ***)
(***                                     ***)

```

```

(***   GROUP-1:  TPDU from DDN-TCP      ***)

```

```

(***   State_transition from CLOSED     ***)

```

trans

```

when TCPM_I.TCPM_MESind (* CR from TCP *)
  provided ((cur_TCP_code(message)=CRCODE)) and (l_ref=0))
    from CLOSED to same

begin (* no conn available *)
  build_ER;
  output TCPM_O.TCPM_MESreq(cur_mes);
end;

```

trans

```

when TCPM_I.TCPM_MESind (* CR from TCP *)
  provided ((cur_TCP_code(message)=CRCODE)) and (l_ref<>0))
    from CLOSED

begin
  accept_TPDU (message); (* take in the TPDU *)
  snd_nxt := time_of_day();
  snd_wnd := 0;
  snd_ack := 0;

  rcv_nxt := seq;
  rcv_wnd := wnd;
  rcv_ack := 0;
  trans_CR;
  output TCPI_O.TCPI_MESreq(tp_mes); (* send translated
                                     message to linker *)
  next_state := SYN_SENTout;
end;

```

```

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = CCCODE)
      from CLOSED to SAME

    begin
      build_ER;
      output TCPM_O.TCPM_MESreq(cur_mes);
    end;

```

```

trans
  when TCPM_I.TCPM_MESind
    provided ((cur_TCP_code(message) = DTCODE) or
      (cur_TCP_code(message) = AKCODE))
      from CLOSED to SAME

    begin
      proto_err := proto_err+1;
      build_ER;
      output TCPM_O.TCPM_MESreq(cur_mes);
    end;

```

(*** State_transition from SYN_SENTddn ***)

```

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = CCCODE)
      from SYN_SENTddn

    var
      retrans_ptr := ^retrans_type;

    begin
      stop_retrans_timer;          (* for CR *)
      accept_TPDU (message);       (* take in the TPDU *)
      rcv_nxt := seq;
      rcv_wnd := wnd;
      rcv_ack := 0;

      re_trans.total := re_trans.total-1; (* remove CR from
                                           retrans_queue *)

      set_window_timer;
      set_inact_timer;
      trans_CC;
      output TCPI_O.TCPI_MESreq(tp_mes); (* send translated
                                           message to linker *)

      next_state := SYN_RCVDout;
    end;

```

```

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = DRCODE)
      from SYN_SENTddn to TIME_WAIT

    begin
      accept_TPDU (message);          (* take in the TPDU *)
      set_ref_timer;
      trans_DR;
      output_TCPI_O.TCPI_MESreq(tp_mes); (* send TDISind to linker *)
    end;

```

```

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = ERCODE)
      from SYN_SENTddn to TIME_WAIT

    begin
      accept_TPDU (message);          (* take in the TPDU *)
      set_ref_timer;
      build_DRg;
      output_TCPI_O.TCPI_MESreq(tp_mes); (* send TDISind to linker *)
    end;

```

(*** State_transition from SYN_SENTout ***)

```

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = DRCODE)
      from SYN_SENTout to CLOSED

    begin
      accept_TPDU (message);          (* take in the TPDU *)
      build_DC;
      output_TCPM_O.TCPM_MESreq(cur_mes);
      trans_DR;
      output_TCPI_O.TCPI_MESreq(tp_mes); (* send TDISind to linker *)
      flag_kill_me := now;              (* terminate the TPM *)
    end;

```

(*** State_transition from SYN_RCVD ***)

```
trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = CRCODE)
      from SYN_RCVD to SAME

    var
      retrans_ptr: retrans_type;

    begin
      stop_retrans_timer;
      retrans_ptr := re_trans.buf[1];
      output TCPM_O.TCPM_MESreq(retrans_ptr.data); (* retrans CC *)
      retrans_ptr.count := 1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
    end;
```

```
trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = ERCODE)
      from SYN_RCVD to FIN_WAIT

    var
      retrans_ptr: retrans_type;

    begin
      stop_retrans_timer;
      accept_TPDU (message); (* take in the TPDU *)
      retrans_ptr := re_trans.buf[1];
      build_DR;
      output TCPM_O.TCPM_MESreq(cur_mes);
      retrans_ptr.data := cur_mes; (* replace CC with DR *)
      retrans_ptr.count := 1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
      build_DRg;
      output TCPI_O.TCPI_MESreq(tp_mes); (* send TDISind *)
    end;
```

```

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = DRCODE)
      from SYN_RCVD to TIME_WAIT

    begin
      accept_TPDU (message);          (* take in the TPDU *)
      build_DC;
      output_TCPM_O.TCPM_MESreq(cur_mes);
      set_ref_timer;
      trans_DR;
      output_TCPI_O.TCPI_MESreq(tp_mes); (* send TDISind *)
    end;

```

(*** State_transition from SYN_RCVDddn ***)

```

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = DTCODE)
      from SYN_RCVDddn to ESTAB

    begin
      stop_retrans_timer;          (* no more re-trans CC *)
      re_trans.last := 0;          (* clear re-trans queue *)

      accept_TPDU (message);        (* take in the TPDU *)
      trans_DT;
      output_TCPI_O.TCPI_MESreq(tp_mes);
      set_inact_timer;
      set_inact_ack_timer;          (* for sending AK at suitable
                                     interval in absence of DT *)
    end;

```

(*** State_transition from ESTAB ***)

```

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = CRCODE)
      from ESTAB to SAME

    begin
      stop_inact_timer;
      set_inact_timer;
    end;

```

```

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = CCCODE)
      from ESTAB to SAME

    begin
      stop_inact_timer;
      build_AK;
      output TCPM_O.TCPM_MESreq (cur_mes);
      set_inact_timer;
      end;

      (* duplicated CC *)
      (* repeat AK *)

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = ERCODE)
      from ESTAB to SAME

    var
      retrans_ptr: retrans_type;

    begin
      stop_window_timer;
      stop_inact_timer;
      stop_retrans_timer;
      accept_TPDU (message);
      build_CR;
      output TCPM_O.TCPM_MESreq(cur_mes);
      end;

      (* take in the TPDU *)
      (* Re-synchronize *)

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = DRCODE)
      from ESTAB to TIME_WAIT

    var
      retrans_ptr: retrans_type;

    begin
      stop_retrans_timer;
      accept_TPDU (message);
      build_DC;
      output TCPM_O.TCPM_MESreq(cur_mes);
      build_DR;
      output TCPM_O.TCPM_MESreq(cur_mes);
      set_ref_timer;
      end;

      (* take in the TPDU *)
      (* TCP has order-release! *)

```



```

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = DTCODE)
      from ESTAB to SAME

    begin
      stop_inact_timer;
      accept_TPDÜ (message);          (* take in the TPDÜ *)

      if (seq = rcv_nxt) then          (* DT in sequence *)
        begin
          trans_DT;
          output_TCPI_O.TCPI_MESreq(tp_mes);
          set_data_ack_timer;          (* set timer to ack
                                         during A_l *)
          rcv_nxt := rcv_nxt + d_length(cur_tcp.data);
          while ((re_order.last > 0) and (* check re-seq queue *)
                (rcv_nxt = re_order.buf[1].seq)) do
            begin
              message := re_order.buf[1].data;
              trans_DT;
              output_TCPI_O.TCPI_MESreq(tp_mes);
              rcv_nxt := rcv_nxt + d_length(re_order.buf[1].data);
              for i := 2 to re_order.last do
                re_order.buf[i-1] := re_order.buf[i];
              re_order.last := re_order.last - 1;
            end;
          else if ((seq < rcv_nxt) or (seq > rcv_nxt + rcv_wnd)) then
            (* out of window *)
            begin
              build_ER;
              output_TCPM_O.TCPM_MESreq(cur_mes);
            end;
          else
            begin
              (* not-in-seq handling *)
              j := 0;
              for i := 1 to re_order.last do
                if ((seq > re_order.buf[i].seq) and (j = 0)) then
                  j := i;
                for i := j to re_order.last do
                  re_order.buf[i+1] := re_order.buf[i];
                re_order.buf[j].seq := seq;
                re_order.buf[j].data := message;  (* queued *)
              end;
            set_inact_timer;
          end;
        end;
      end;

```

```

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = AKCODE)
      from ESTAB to SAME

    begin
      stop_inact_timer;
      stop_retrans_timer;
      accept_TPDU (message);          (* take in the TPDU *)

      if (seq > snd_ack) then          (* AK in sequence *)
        begin
          snd_ack := seq;
          while ((re_trans.last>0) and (* check re-seq queue *)
                (snd_ack>=re_trans.buf[1].seq)) do
            begin
              for i:=2 to re_trans.last do
                re_trans.buf[i-1] := re_trans.buf[i];
              re_trans.last := re_trans.last -1;
            end;
          (* else, automatic drop the AK *)
        end;

        if (re_trans.last>0) then
          set_retrans_timer;
          set_inact_timer;
        end;
      end;
    end;
  end;

```

(*** State_transition from FIN_WAIT ***)

```

trans
  when TCPM_I.TCPM_MESind
    provided ((cur_TCP_code(message) = CRCODE) or
              (cur_TCP_code(message) = CCCODE) or
              (cur_TCP_code(message) = DTCODE) or
              (cur_TCP_code(message) = AKCODE))
      from FIN_WAIT to SAME

    var
      reason: reason_type;

    begin
      accept_TPDU (message);          (* take in the TPDU *)
      build_ER;
      output TCPM_O.TCPM_MESreq(cur_mes);
      end;
    end;
  end;

```

```

trans
  when TCPM_I.TCPM_MESind
    provided ((cur_TCP_code(message) = DRCODE) or
              (cur_TCP_code(message) = DCCODE) or
              (cur_TCP_code(message) = ERCODE) )
    from FIN_WAIT to TIME_WAIT

    begin
      set_ref_timer;
    end;

```

(*** State_transition from TIME_WAIT ***)

```

trans
  when TCPM_I.TCPM_MESind
    provided (cur_TCP_code(message) = CCCODE)
    from TIME_WAIT to SAME

    begin
      accept_TPDU (message);          (* take in the TPDU *)
      build_ER;
      output_TCPM_O.TCPM_MESreq(cur_mes);
    end;

```

```

trans
  when TCM_I.TCPM_MESind
    provided (cur_TCP_code(message) = DRCODE)
    from TIME_WAIT to SAME

    begin
      accept_TPDU (message);          (* take in the TPDU *)
      build_DC;
      output_TCPM_O.TCPM_MESreq(cur_mes);
    end;

```

```

(***)  GROUP-2:  timer-related  (***)

trans
  from SYN_SENTddn
    provided (timer(retrans))

    var
      retrans_ptr: ^retrans_type;

    begin
      (* only CR in retrans queue *)
      retrans_ptr := re_trans.buf[1];
      if (retrans_ptr.count < RETRANS_MAX) then
        begin
          output TCPM_O.TCPM_MESreq(cur_mes); (* re-trans CR *)
          retrans_ptr.count := retrans_ptr.count+1;
          retrans_ptr.timer := RETRANS_TIME;
          set_retrans_timer;
          next_state := SAME;
        end;
      else begin
        (* count = max *)
        stop_window_timer;
        stop_inact_timer;
        build_DR;
        output TCPM_O.TCPM_MESreq(cur_mes);
        retrans_ptr.data := cur_mes;
        retrans_ptr.count := 1;
        retrans_ptr.timer := RETRANS_TIME;
        set_retrans_timer;
        build_DRg;
        output TCPI_O.TCPI_MESreq(tp_mes); (* send TDISind *)
        next_state := FIN_WAIT;
      end;
    end;
end;

```

```

trans
  provided (timer(retrans))
    from SYN_RCVD

    var
      retrans_ptr: retrans_type;

    begin
      retrans_ptr := re_trans.buf[1];
      if(retrans_ptr.count < RETRANS_MAX) then
        begin
          output TCPM_O.TCPM_MESreq(cur_mes);    (* retrans CC *)
          retrans_ptr.count := retrans_ptr.count+1;
          retrans_ptr.timer := RETRANS_TIME;
          set_retrans_timer;
          next_state := SAME;
        end;
      else
        (* count = max *)
        begin
          stop_window_timer;
          stop_inact_timer;
          build_DR;
          output TCPM_O.TCPM_MESreq(cur_mes);
          retrans_ptr.data := cur_mes;    (* replace CC with DR *)
          retrans_ptr.count := 1;
          retrans_ptr.timer := RETRANS_TIME;
          set_retrans_timer;
          build_DRg;
          output TCPI_O.TCPI_MESreq(tp_mes);    (* send TDISind *)
          next_state := FIN_WAIT;
        end;
      end;
    end;

```

```

trans
  from ESTAB
    provided (timer(retrans))

    var
      retrans_ptr: retrans_type;

    begin
      retrans_ptr := re_trans.buf[1];
      if (retrans_ptr.count < RETRANS_MAX) then
        begin
          output TCPM_O.TCPM_MESreq(retrans_ptr.data);
          retrans_ptr.count := retrans_ptr.count+1;
          retrans_ptr.timer := RETRANS_TIME;
          set_retrans_timer;
          check_queue;    (* check for re-trans *)
          next_state := SAME;
        end;
      end;
    end;

```

```

end;
else begin
    stop_window_timer;
    stop_inact_timer;
    re_trans.total := 1;
    retrans_ptr := re_trans.buf[1];
    build_DR;
    output TCPM_O.TCPM_MESreq(cur_mes);
    retrans_ptr.data := cur_mes;
    retrans_ptr.count := 1;
    retrans_ptr.timer := RETRANS_TIME;
    set_retrans_timer;
    build_DRg;
    output TCPI_O.TCPI_MESreq(tp_mes); (* send TDISind *)
    next_state := FIN_WAIT;
end;

```

```

trans
provided (timer(retrans))
from FIN_WAIT

var
    retrans_ptr: retrans_type;

begin
    retrans_ptr := re_trans.buf[1];
    if (retrans_ptr.count < RETRANS_MAX) then
        begin
            output TCPM_O.TCPM_MESreq(cur_mes);
            retrans_ptr.count := retrans_ptr.count+1;
            retrans_ptr.timer := RETRANS_TIME;
            set_retrans_timer;
            next_state := SAME;
        end;
    else
        begin
            set_ref_timer;
            next_state := TIME_WAIT;
        end;
    end;
end;

```

```

trans
  provided (timer(window))
    from ESTAB to SAME          (* need to update window info *)

    var
      retrans_ptr: retrans_type;

    begin
      rcv_wnd := set_window;    (* get new credit *)
      build_AK;
      append_flow;              (* append flow-ctrl parameters *)
      output_TCPM_O.TCPM_MESreq(cur_mes);
      re_trans.last := re_trans.last + 1;
      retrans_ptr := re_trans.buf[re_trans.last];
      retrans_ptr.data := cur_mes;
      retrans_ptr.count := 0;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
      set_window_timer;
    end;

```

```

trans
  provided (timer(data_ack))
    from ESTAB to SAME          (* timer for acknowledge of
                                receiving data *)

    begin
      rcv_ack := rcv_nxt;
      build_AK;
      output_TCPM_O.TCPM_MESreq(cur_mes);
    end;

```

```

trans
  provided (timer(inact_ack))
    from ESTAB to SAME          (* no DT/ED sent in the interval;
                                sending AK to keep active *)

    begin
      build_AK;
      output_TCPM_O.TCPM_MESreq(cur_mes);
      set_inact_ack_timer;
    end;

```

```

trans
  provided (timer(inact))
    from ESTAB to FIN_WAIT

    var
      retrans_ptr: retrans_type;

    begin
      stop_window_timer;
      stop_retrans_timer;
      build_DR;
      output TCPM_O.TCPM_MESreq(cur_mes);
      re_trans.total := 1; (* remove all retrans *)
      retrans_ptr := re_trans.buf[1];
      retrans_ptr.data := cur_mes;
      retrans_ptr.count := 1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
      build_DRg;
      output TCPI_O.TCPI_MESreq(tp_mes); (* send TDISind to linker *)
      end;

trans
  provided (timer(ref))
    from TIME_WAIT to CLOSED

    begin
      flag_kill_me := now
    end;

```


(*** GROUP-3: TPDU from TRANSPORT GATEWAY ***)

```
trans
  when TCPI_I.TCPI_MES.ind (* CR from gateway *)
    provided (TP_code(message) = CRCODE)
      from CLOSED to SYN_SENTddn

    var
      retrans_ptr: retrans_type;

    begin
      accept_TP_mes (message); (* take in the TP_mes *)
      rcv_wnd := set_window;
      trans_CRg;
      output TCPM_O.TCPM_MESreq(cur_mes);
      re_trans.total := 1;
      retrans_ptr := re_trans.buf[1];
      retrans_ptr.data := cur_mes;
      retrans_ptr.count := 1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
    end;
```

```
trans
  when TCPI_I.TCPI_MESind
    provided (TP_code(message) = DRCODE)
      from SYN_SENTddn

    var
      retrans_ptr: retrans_type;

    begin
      accept_TP_mes (message); (* take in the TP_mes *)
      stop_retrans_timer;
      accept_TP_mes (message); (* take in the TP_mes *)
      trans_DRg;
      output TCPM_O.TCPM_MESreq(cur_mes);
      re_trans.total := 1;
      retrans_ptr := re_trans.buf[1];
      retrans_ptr.data := cur_mes;
      retrans_ptr.count := 1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
    end;
```

```

trans
  when TCPI_I.TCPI_MESind
    provided (TP_code(message) = CCCODE)
      from SYN_SENTout to SYN_RCVDddn

    var
      retrans_ptr: retrans_type;

    begin
      accept_TP_mes (message);          (* take in the TP_mes *)
      rcv_wnd := set_window;
      trans_CCg;
      output_TCPM_O.TCPM_MESreq(cur_mes);
      re_trans.total := 1;
      retrans_ptr := re_trans.buf[1];
      retrans_ptr.data := cur_mes;
      retrans_ptr.count := 1;
      retrans_ptr.timer := RETRANS_TIME;
      set_retrans_timer;
    end;

```

```

trans
  when TCPI_I.TCPI_MESind
    provided (TP_code(message) = DRCODE)
      from SYN_SENTout to CLOSED

    begin
      accept_TP_mes (message);          (* take in the TP_mes *)
      trans_DRg;
      output_TCPM_O.TCPM_MESreq(cur_mes);
      flag_kill_me := now;
    end;

```

```

trans
  when TCPI_I.TCPI_MESind
    provided (TP_code(message) = DRCODE)
      from SYN_RCVDddn to FIN_WAIT

    var
      retrans_ptr: retrans_type;

    begin
      stop_retrans_timer;
      accept_TP_mes (message);          (* take in the TP_mes *)
      trans_DRg;
      output_TCPM_O.TCPM_MESreq(cur_mes);
      retrans_ptr := re_trans.buf[1];
      retrans_ptr.data := cur_mes;
    end;

```

```

retrans_ptr.count := retrans_ptr.count+1;
retrans_ptr.timer := RETRANS_TIME;
set_retrans_timer;
end;

```

```

trans
when TCPI_I.TCPI_MESind
  provided (TP_code(message) = DTCODE)
    from SYN_RCVD to ESTAB

  begin
    stop_inact_ack_timer;
    accept_TP_mes (message);          (* take in the TP_mes *)
    trans_DTg;
    output_TCPM_O.TCPM_MESreq(cur_mes); (* send DT to TCP Net *)
    retrans_ptr := re_trans.buf[1];
    retrans_ptr.data := cur_mes;
    retrans_ptr.count := retrans_ptr.count+1;
    retrans_ptr.timer := RETRANS_TIME;
    set_retrans_timer;
    set_window_timer;
    set_inact_timer;
    set_inact_ack_timer;
  end;

```

```

trans
when TCPI_I.TCPI_MESind
  provided (TP_code(message) = DRCODE)
    from ESTAB to FIN_WAIT

  var
    retrans_ptr: retrans_type;

  begin
    stop_window_timer;
    stop_inact_timer;
    stop_retrans_timer;
    accept_TP_mes (message);          (* take in the TP_mes *)
    trans_DRg;
    output_TCPM_O.TCPM_MESreq(cur_mes);
    retrans_ptr := re_trans.buf[1];
    retrans_ptr.data := cur_mes;
    retrans_ptr.count := retrans_ptr.count+1;
    retrans_ptr.timer := RETRANS_TIME;
    set_retrans_timer;
  end;

```

```

trans
  when TCPI_I.TCPI_MESind
    provided (TP_code(message) = DTCODE)
      from ESTAB to SAME

    begin
      stop_window_timer;
      stop_inact_timer;
      accept_TP_mes (message);          (* take in the TP_mes *)
      trans_DTg;
      output TCPM_O.TCPM_MESreq(cur_mes);
      retrans_ptr := re_trans.buf[re_trans.last];
      retrans_ptr.data := cur_mes;
      retrans_ptr.count := retrans_ptr.count+1;
      retrans_ptr.timer := RETRANS_TIME;
      re_trans.last := re_trans.last + 1;
      set_retrans_timer;
      set_window_timer;
      set_inact_timer;
    end;

```

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